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ETL-0310

APPS—IV civil works data extraction/data base application study (phase 1)

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ENGINEER TOPOGRAPHIC LABORATORIES
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This report describes the Computer-Assisted Photo Interpretation Research (CAPIR) facility assembled at the U.S. Army Engineer Topographic Laboratories and discusses the implementation and applications of such a system in the Corps of Engineers' Civil Works Program. Following an exposition on the system, a demonstration project performed for the Detroit District by Autometric, Inc. is described. In this demonstration, the CAPIR system was applied to a flood damage potential study. The particular applications were structure mapping and land use interpretation. A Civil Works "User Scenario" is also included in this report.

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APPLICATION STUDY (PHASE 1)

Prepared for

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Preface

This report was generated under Contract DAAK70-81-C-0261 for the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia 22060, by Autometric, Inc., Falls Church, Virginia. The Contracting Officer's Technical Representative was Laslo Greczy. The Contract Program Manager was Jonathan Howland. Major contributions to this report were made by Dr. Clifford Greve, Mr. Harry Niedzwiadek, Mr. Richard Pascucci, and Dr. Carl Reed, all of Autometric, Incorporated.

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1.0 INTRODUCTION

In 1979, the U.S. Army Engineer Topographic Laboratories initiated a program in Computer-Assisted Photo Interpretation Research (CAPIR) as an effort to bridge the gap between manual image analysis products and large volume requirements for digital map data of the Defense Mapping Agency and other military agencies. The main objective of CAPIR was to support a human specialist with hardware and software in order to make stereoscopic photo interpretation easier, faster, and more accurate than existing Photo Interpretation (PI) procedures. This lead to the development of the CAPIR System.

The main thrust of CAPIR has been military, but the system also has great potential in civil works applications. The Engineer Topographic Laboratories (ETL) has awarded a two-phase contract to Autometric, Inc. to identify, evaluate and demonstrate potential applications of CAPIR technology to Corps civil works projects.

During the first phase of this contract Autometric identified and developed test plans for three civil works demonstration projects. One of these demonstrations, Detroit District's Clinton River project, was performed during Phase I. This report describes that demonstration. In addition, a Civil Works User Scenario, describing system capabilities and potential applications not demonstrated during the course of the contract, was also developed during Phase I, and included in this report.

During the second phase of this study, Autometric will perform demonstrations in conjunction with Portland District (Columbia River project) and Seattle District (Fort Lewis project). A test plan describing the work to be performed during both of these demonstrations is included as Appendix C of this report. In addition, Autometric will prepare documentation containing recommendations on the implementation of CAPIR technology by the Corps of Engineers.

This document is the Final Technical Report for Phase I of the contract. It includes a description of the CAPIR system and its applications as well as details of the demonstration performed for the Detroit District.

2.0 COMPUTER-ASSISTED PHOTO INTERPRETATION RESEARCH AT USAETL

2.1 The CAPIR Concept

Photo interpretation is a widely accepted means of using remotely sensed data (imagery) for the purpose of identifying, measuring, and evaluating the significance of features on the Earth's surface. The task of a photo interpreter is generally extremely complex in nature. The PI should first have confidence in his understanding of all environmental and system parameters relating to the imagery, and he must comprehend the basic properties of the features he wishes to identify. Furthermore, it is not sufficient for the photo interpreter to rely exclusively on information derived from the imagery. He must have knowledge of related fields of study (e.g., geology, biology) in order to understand the complex arrangements and systematic patterns often encountered on Earth. Finally, the PI is usually given the responsibility for extracting the feature information so that a map portraying the information can be produced. Considering all the variables in the photo interpretation process, especially when a map product is required, it is highly desirable to exploit current technology in order to aid the PI and produce more accurate and presentable results in a timely, cost-effective manner.

Today, photo interpreters use basically the same tools in their work as PI's have used for decades. The stereoscope is still the most important instrument used in photo interpretation, and simple mensuration devices, such as planimeters and parallax bars are also used when dimensional information is required. Devices based on the camera lucida principle, like the Vertical Sketchmaster and B&L Zoom Transfer Scope, permit the PI to transfer features from imagery to a base manuscript. The photo interpreter needs collateral information to aid him in his work. Interpretation keys are very beneficial when numerous complicated properties must be understood for an interpretation task. This is particularly true for the biological and physical sciences (e.g. wetlands interpretation). Information contained on maps is also important for photo interpretation. Given these tools, and through no small effort, the PI manages to accomplish his work.

Approximately three years ago, ETL recognized the value of

certain technological developments and the way in which they might be used to assist a PI. The major developments consisted of the APPS-IV analytical plotter and the AUTOGIS geographic information system. The APPS-IV, interfaced with a digital computer, would permit a PI to view photographs in stereo for analysis and identification purposes and also, with its mensuration capabilities, enable the PI to determine the dimensions of features and locate them on the Earth's surface. AUTOGIS is a comprehensive software package, initially developed for the U.S. Fish and Wildlife Service, that provides the necessary man-machine interface, as well as a host of other functions such as geographic data base management and map analysis and display. Together the APPS-IV and AUTOGIS form the nucleus for the Computer-Assisted Photo Interpretation Research (CAPIR) efforts planned by ETL.

2.2 CAPIR Hardware

The CAPIR system's hardware consists of a host computer with peripherals, the APPS-IV analytical plotter, a X, Y digitizing tablet, and a voice recognition unit. (See Figure 1.)

2.2.1 Host Computer

The CAPIR system is supported by a Data General Eclipse S/250 minicomputer with Integral Array Processor. Standard peripherals include 800 and 1600 bpi magnetic tape drives, a 192 Mbyte disk, CRT display terminals, a system console, and a printer. A Versatec electrostatic plotter provides high-speed hard-copy graphics. The AUTOGIS software has also been converted to a DEC 11/70 minicomputer.

2.2.2 The APPS-IV Analytical Plotter

The APPS-IV (see Figure 2) is a medium accuracy analytical plotter ($\pm$ 10 micrometers). It consists of an optical system for viewing stereo photographs, a mechanical system with a unique stage on stage design that permits significant compactness as compared to other instruments of similar accuracy, and an electronic system. Thirteen microprocessors perform all servo-motor functions for stage positioning and all communications with

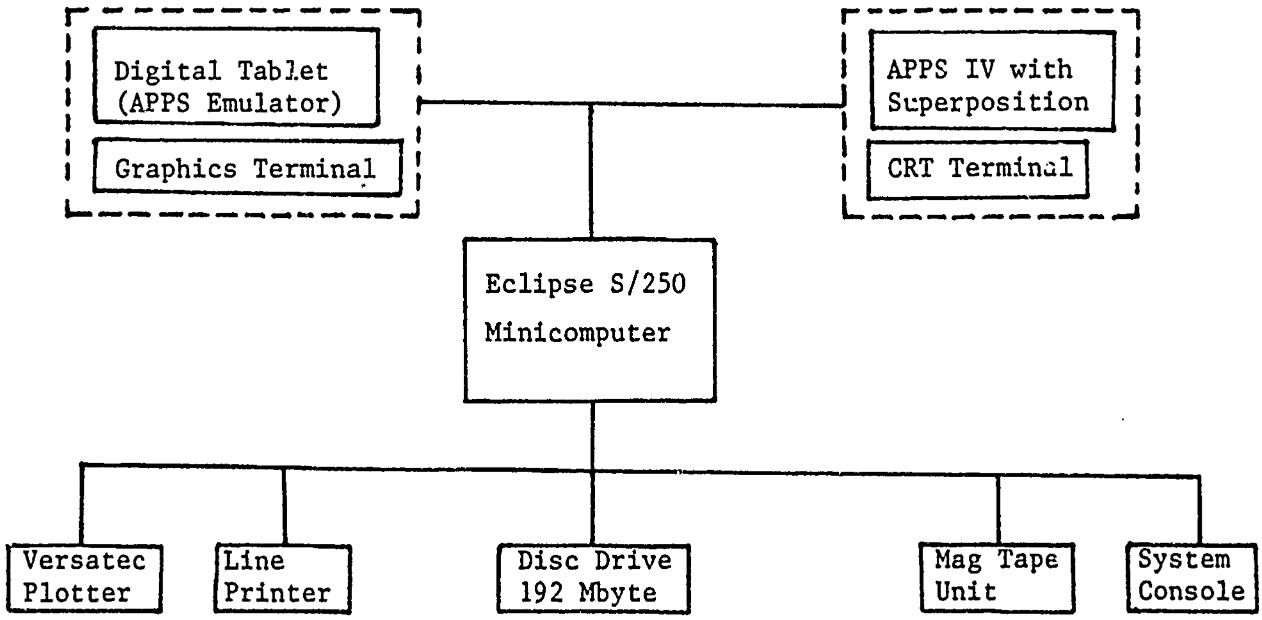


Figure 1

Computer Assisted Photo Interpretation
Research (CAPIR) Facility

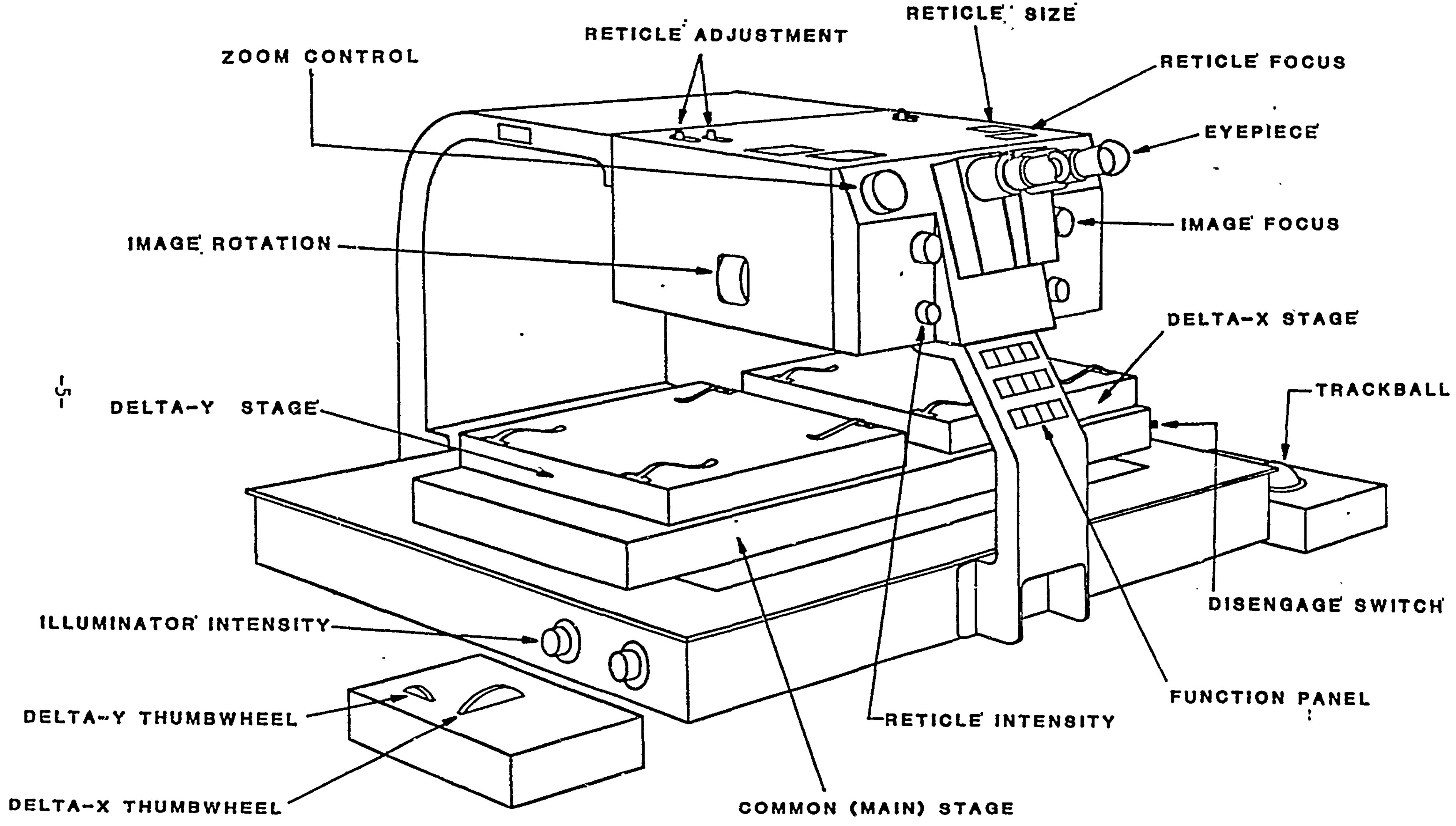


Figure 2. APPS-IV Stereoplotter

the host computer. The instrument will accommodate imagery with formats of up to nine-by-nine inches. The primary function of the APPS-IV is to insure that a stereo photographic model is precisely maintained at all times while it is viewed and measured. The instrument will also automatically drive to a specific point in the imagery, an operation necessary for activities such as collecting profile data and useful for many other applications. The instrument provides controls for manually positioning the stages (a trackball for common base-stage motion in x and y and thumbwheels for relative x and y positioning of the upper photo-stages), for collecting measurements (foot pedal), and for changing system functions (a series of pushbuttons).

Stereo model maintenance, a requirement for any photo interpretation activity, is possible for all types of projective imagery (e.g., frame, focal plane shutter and panoramic), as well as for radar imagery. The APPS-IV accomplishes this without continous communication with the host computer. Once the model parameters are downloaded to the instrument, it operates independently of the host. The microprocessors monitor stage position and perform the computations required to update the relative positions of the photo-stages.

One of the more notable features of the APPS-IV is its new optical system, the Model 3500 OEM Zoom Stereoscope. The system has a 6 to 36 power zoom range, capable of high contrast resolution in excess of 250 line pairs per millimeter at 36 power. Controls are provided for image rotation and y-phoria correction. An illuminated reticle projection system with 10-, 25-, 50- and 100-micron dot sizes is included for measurement purposes. Camera ports for TV cameras are provided to allow viewing by other people "as the operator sees it." The incorporation of these optics into the APPS-IV is significant for photo interpretation purposes because the high power and high-resolution available with this system is required for most photo interpretation tasks, particularly when high-resolution, high-altitude imagery is properly used.

2.2.2.1 Graphics Superposition on the APPS-IV

The most significant enhancement made to the APPS-IV instrument for the CAPIR system is the development of graphics superposition. Graphics superposition provides the capability to view graphics from a stroke-refresh type of CRT optically superimposed on a stereo model (see Figure 3). The graphics seen on the CRT represent digitally encoded features that have been produced with the APPS-IV or through some other means. An additional microprocessor in the APPS-IV constantly monitors stage position and "commands" the CRT processor to move the graphics on the CRT to correspond with stage movement so that the graphics appear to precisely overlay the imagery.

One of the major responsibilities of a photo interpreter is knowing what he has already interpreted and how the features tie to a map base. With graphics superposition, map boundaries can be seen over the imagery and the "electronic pencil" property of the system can be used to show features that have been identified and digitized, as well as features that are currently being digitized.

By adding a second graphics display to the system, the operator can view graphics in stereo. These graphics will produce a stereo model, from three-dimensional input data. An interesting effect that the operator will notice is that digitally encoded features may not overlay the imagery exactly. This anomaly is usually caused by errors in the original digitization. The apparent result is graphically depicted features that are offset or that "float" above or below the ground surface as seen in the imagery. Graphics superposition minimizes these anomalies by aiding the PI in keeping the floating measuring mark on the surface of the feature being digitized.

Another advantage of graphics superposition, and an aid in analysis, is the ability to view ancillary digitally-encoded information. For example, a photo-geologist can view aeromagnetic lines or seismic survey results superimposed on his imagery. This information helps to highlight geologic features that might not be noticed under normal circumstances.

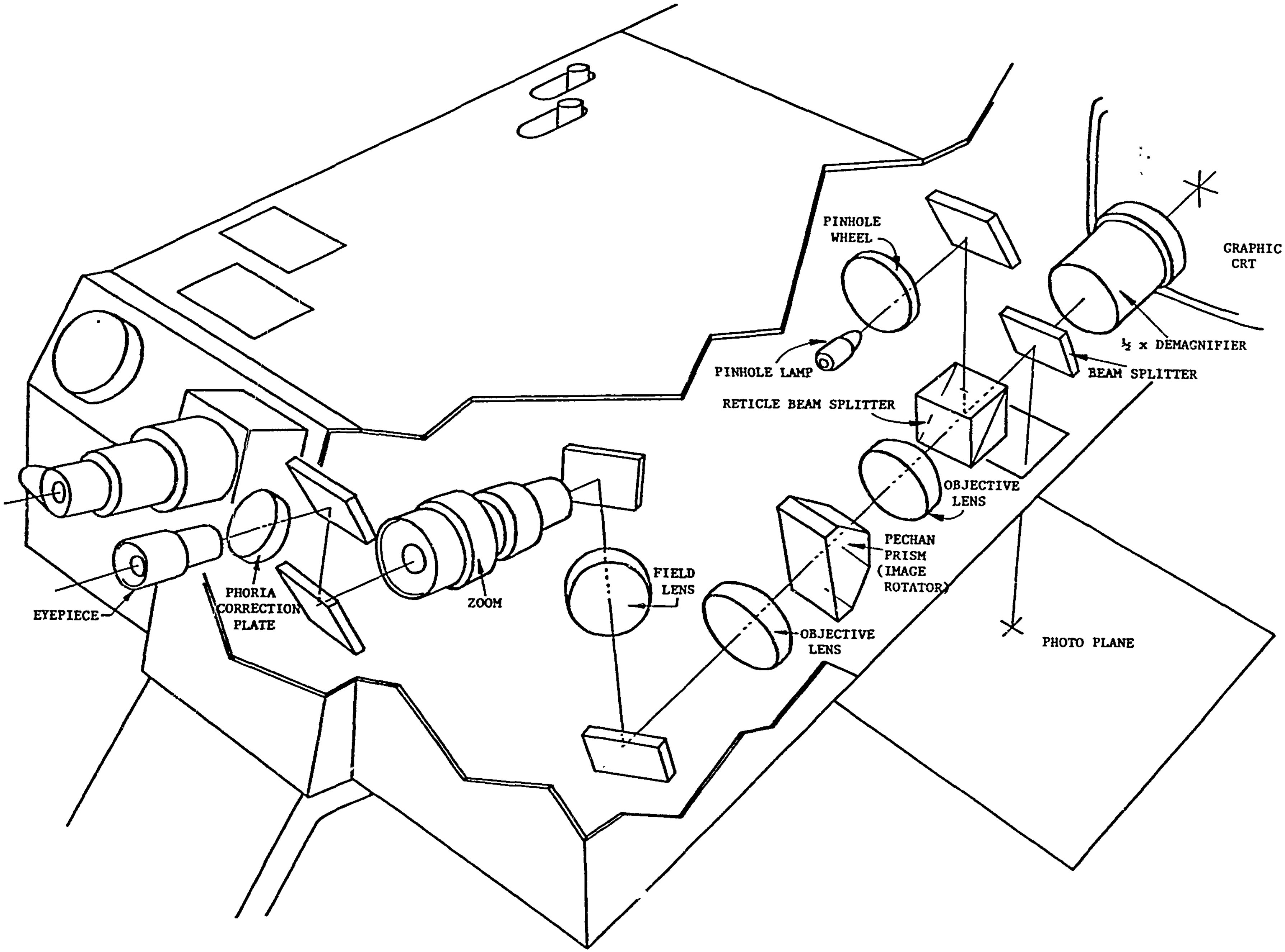


Figure 3 - Graphics Superposition on the APPS-IV

2.2.3 Monoscopic Workstation

The monoscopic workstation is a commercial 36" x 48" table mounted, back-lighted, digital tablet. A special purpose "black box" has been interposed between the RS-232c output of the table and the RS-232c port of the host computer, so that signals from the tablet are reformatted, buffered, and transmitted with full error control, as with the APPS-IV.

2.2.4 Other Hardware

A voice recognition unit is currently being integrated into the CAPIR system so that the operator can communicate with the host from the APPS-IV while maintaining visual contact with his work.

2.3 Software

The Software of the CAPIR system consists of the host computer's software and AUTOGIS geographic information system software.

2.3.1 Host Software

The host software operates under the Data General Advanced Operating System (AOS), providing a multi-user, multi-tasking environment. System libraries consist of the International Mathematical and Statistics Library (IMSL), high-level Array Processor software, and graphics routines for Calcomp, Imlac, Tektronix, and Versatec devices. Supported compilers include Fortran V, Pascal, and assembly language. System utilities include line and screen editors, a document processor, and a DG sort/merge package.

2.3.2 Geographic Information System Software

The CAPIR system supports direct data entry from either the APPS-IV or from the digitizing table to a general purpose Geographic Information System(GIS). The GIS is Autometric's commercially available AUTOGIS and is composed of two main components: The Analytical Mapping System (AMS), and the Map Overlay and Statistical System (MOSS).

2.3.2.1 AMS

The Analytical Mapping System suports four main capabilities: analytical aerotriangulation, digitization from the APPS-IV or X-Y tablet, spatial verification, and data base management.

2.3.2.1.1 Aerotriangulation Subsystem

An interactive aerotriangulation capability is used to compute the camera station parameters for the aerial photos to be used in stereo digitization on the APPS-IV. Using ground control derived from geodetic files or topographic map sheets, and photo coordinates measured on the APPS-IV, a rigorous bundle adjustment program solves for camera station parameters of position and orientation for as many as ten frames. The operator is led through the triangulation procedure by a sequence of menus featuring capabilities for on-line data inspection and editing, analysis of triangulation results and process control.

Both metric and non-metric (e.g., Hasselblad 500EL) cameras have been triangulated successfully using the aerotriangulation software.

A single-model triangulation program has been developed for the panoramic optical bar camera system, and it is possible to digitize from this source. In addition, a single stereo model, side-looking radar triangulation program is accommodated in AMS. These features will be explained further in Section 3.5.

2.3.2.1.2 Digitizing Subsystem

AMS produces three basic elements of information during the digitizing process, namely: (1) arcs, (2) nodes, and (3) attributes (feature labels). Figure 4 illustrates these elements.

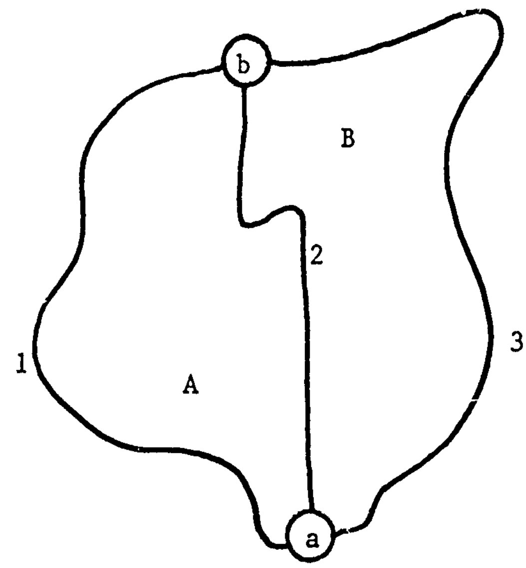


Figure 4 - AMS Information Elements

This figure shows two different feature types, A and B. The areas are delineated on the outside by arcs 1 and 3 for A and B, respectively. Arc 2 represents the common boundary. The two nodes, a and b, are where the arcs begin or end. All arcs meet at the nodes. To illustrate the significance of attributes, consider that arc 2 is digitized from node a to b. In this case, feature A is on the left and B on the right. Therefore arc 2 has a left attribute of A and a right attribute of B. Its center attribute is null. The center attribute is used for lineal features as opposed to polygonal features.

The node type depicted in Figure 4 is called a normal node. There are two other types of nodes: temporary and edge. A temporary node is one used when a feature runs between stereo models or maps that are being digitized. It is typically formed at the edge of the model or map and serves as a tie point. An edge node is like a temporary node, except that it is formed along the boundary between the "rectangular" geographic areas which serve as the logical unit of division in the data base, referred to as geounits. The edge node is formed automatically as one digitizes over a geounit boundary. The corresponding edge nodes between two adjacent geounits have identical coordinates.

There are three different modes of digitizing: (1) point; (2) curve; and (3) stream. In the point mode, the discrete points that delineate the feature are picked by the operator. This is generally used for straight features. The curve mode is like the point mode in the manner in which points are picked; however, cubic curves are fitted between points. This mode is useful when the feature being digitized can be represented by a gentle, breaking curve. The stream mode is used for intricate features. In this mode, points are picked automatically at a specific distance interval as the feature is traced.

The editing of the data can occur at two different times during the digitizing process. If a mistake is made while an arc is being digitized, the operator has two options: either the entire arc can be deleted from the data set and started over again, or the end portion of the arc can be "clipped off" and redigitized. If the arc has already been completed and must be redone, the operator identifies it, and it is then automatically deleted from the data set. The operator can also change attributes, and delete a node or completed polygon (i.e., all arcs associted with the node or polygon).

During the digitizing, encoded spatial data are displayed on a separate graphics terminal and, optionally, in the APPS-IV stereomodel via the superposition displays. Previously created data entries can be recalled, displayed, and edited.

The digitizing capabilities of the system include the creation, display, edit, and storage of Digital Elevation Model (DEM) data, such as a DMA DTED. The DEM is created using the microprocessors that are integral to the APPS-IV in an elevation profiling procedure in which the stages are driven along a grid lattice specified by the program. The APPS-IV automatically samples elevations, while the operator is responsible for maintaining the floating dot on the surface of the stereo model. Stereo superposition is used to mark elevation points already collected. The array of "floating" dots offers the operator an effective digital and perceptual representation of the surface of the earth. Applications of DEM data will be discussed in later sections of this report.

2.3.2.1.3 Data Verification

When the digitizing for a geounit has been completed, a data verification process is performed. In this process the feature data are checked automatically for topological validity. As a result, arcs are tied together to form polygons, and the respective areas are computed. This procedure occurs relatively quickly with the operator standing by to make corrections to the data set when an error is encountered. In this case, the system reports the exact cause and location of the error. When the verification process has been completed, the results can be stored in the data base.

2.3.2.1.4 Data Base Subsystem

The geographic data base in AMS has a simple structure due to the use of the "geounit" as the fundamental division of information. The geounit structure is easily illustrated by a USGS Topographic Map Series Index Map, in which the individual quadrangles are equivalent to geounits. Because of this structure, redundancy in the data base is not a problem, and features that cross geounit boundaries are handled easily.

The data base programs maintain an index to the location of all the digitized data. Normally the data are stored on magnetic tape or disc. The index also defines the status of each geounit, i.e., being digitized, being updated or databased in valid form.

Any geounit stored in the data base can be queried or plotted. The queries provide statistical summaries describing the type, quantity and area of features on a geounit basis. Features may be automatically labelled on the plot if desired.

2.3.2.2 Map Overlay and Statistical System (MOSS)

MOSS is an interactive, spatial analysis, and display software system.

Once a map or photograph has been digitized using AMS, it is transferred to the MOSS analysis and display database. During the transfer process, the coordinate data are transformed from Latitude/Longitude to UTM, Lambert Conformal, Polyconic, or Albers coordinates for the actual data analysis.

MOSS is a completely interactive system that can also be run in batch mode for the storage, retrieval, analysis and display of digital map data. Projects as small as one map sheet or as large as hundreds of map sheets may be handled with equal ease. To date, MOSS has been used for Environmental Impact Statement work, habitat analysis, wildlife refuge management, terrain analysis, geologic interpretation, strip mine leasing alternatives analysis, reservoir studies, wetlands change detection, and general report generation and mensuration.

MOSS can store and allow the user to access point data, line data, polygon data, point elevation data, raster (grid cell) data, Digital Terrain Models (DTM), and binary bit maps in the same session. There are also facilities for changing from one data type to another, such as polygon to raster. It is possible for the user to mix raster data, DTM data, and vector data on the same display. There are a number of methods for retrieving data from the database. Attribute selection, size selection, and proximity selection are all supported for vector data, and boolean or arithmetic selection is available for raster filtering. There are 65 different analysis and display functions that can be applied to the data once they have been retrieved from the data base.

A current list of MOSS commands is described in Appendix A.

3.0 CAPIR APPLICATIONS AND IMPLEMENTATION IN THE CORPS OF ENGINEERS

3.1 GIS Background In the Corps

The Corps of Engineers (COE) has been an active user of remotely sensed data since the 1930's. In the early years, the Corps used conventional aerial photography for site planning, topographic map compilation, project documentation, and engineering design. As technology has developed, the Corps has kept pace, using new photogrammetric procedures and testing and evaluating such new sensors as ground and airborne radar, multi-spectral scanners (including satellite-borne systems), airborne lasers for both bathymetric and topographic information, and in-situ sensors relaying many types of information to data relay satellites. Vast quantities of other useful data are increasingly available, in both hard copy and digital format. Effective acquisition and use of this wealth of data warrant the use of computer-based geographic information systems (GIS). This family of software systems is used to assemble and catalog geographically referenced information into a computer data base from which it can be used for many types of analysis.

The Corps of Engineers has completed many studies using GIS techniques and capabilities in such areas as hydrologic modelling, flood damage analysis, wildlife habitat assessment, land use analysis, and demographic assessment. A Corps-developed GIS (HEC-SAM), developed primarily for water resources management, has played a major role in many of these studies.

The APPS/CAPIR system offers useful photogrammetric and GIS technology to the Corps, including a powerful data entry system and a data import/export compatibility with other GIS systems currently in use in the Corps and elsewhere.

CAPIR technology or its components are being used in a number of studies either funded entirely by the Corps of Engineers or funded jointly by the Corps and other agencies. Since such project work will continue into the future, it is important to consider how best to incorporate CAPIR technology into ongoing COE activities.

This section of the report will discuss: 1) current COE related projects using CAPIR technology, 2) approaches to future integration of CAPIR technology into COE activities, 3) problem areas affecting any integration, and 4) other applications and technical developments of CAPIR.

3.2 Current and Past GIS Projects

During the past year, components of CAPIR have been used for a variety of projects that were funded in whole or in part by the COE. Most of this work has been done in conjunction with the National Coastal Ecosystems Team (NCET) of the U.S. Fish and Wildlife Service in Slidell, Louisiana. NCET utilizes a Data General S-250 Eclipse, a 36" plotter, and four digitizing stations. All of its project work has been accomplished using AUTOGIS, an integral part of the CAPIR technology. While NCET does not currently use the APPS-IV for any of their work, its personnel are seriously considering doing a demonstration project in Fiscal '83 using APPS technology. This will bring one facet of remote sensing into NCET's work for COE. In addition to the APPS interface, NCET is contracting with Autometric to design and program an interface between AUTOGIS and ELAS, which is a system developed by NASA and used to perform LANDSAT processing. NCET considers this interface to be vital for future regional coastal assessments, inventory, and change detection.

3.2.1 Mississippi Active Delta Study

In this study, the Corps needed to determine both rates and types of loss or change in the active portion of the lower Mississippi Delta. To accomplish this task, 17 1:24,000-scale quads were digitized using AUTOGIS. The relevant categories of information were wetlands in 1956 and wetlands in 1978. The base wetlands maps were obtained from the National Wetlands Inventory.

Once the data base was built, the polygon overlay function in MOSS was used to determine change. Area tables of the resultant overlaid maps provided the data on rate of change and type of change. A large color plot of cartographic quality was made to visually depict the spatial characteristics of the changes.

The next step in this project is to develop a trend line. COE hopes to have NCET repeat the analysis using 1981 photography.

3.2.2. Port Studies

NCET is involved with the COE in a number of Port studies, two of which are on the Gulf Coast and the third on the East coast.

The ports of Pascagoula and Mobile are being evaluated for channel deepening. Both of these ports have been earmarked for use by large freighters shipping U.S. coal to foreign ports. In order to accomplish this, the channels must be deepened from 30 feet to 55 feet. The problem is to determine spoil dump locations that will have the least environmental impact. NCET is digitizing a number of different categories of information at different scales using AUTOGIS. One small scale will be used to perform regional assessments for possible dump sites, and site-specific studies will be performed to determine the best dump locations.

3.3 Incorporating CAPIR Technology into COE Activities

To date, the work NCET has performed for COE has resulted in sets of final products, such as area reports and computer generated maps. The actual database and analytics were created and performed by NCET at their facility. However, several COE district offices are in the process of determining the most feasible methods for obtaining access to their own respective project databases at NCET and actually doing the analysis and cartographic display themselves. The options range from dial-in modems to actually converting AUTOGIS to operate on their own Harris minicomputers. This obviously raises the question as how best to integrate a technology such as CAPIR into a large organization such as the COE.

3.3.1 Defining a Need

Before any group within COE should begin to think about adopting a CAPIR type technology, they must be prepared to demonstrate a clearly-defined need. Such a need might be a mandate to monitor changes along a river or coastal area or the requirement to develop a flood management plan for a

drainage area. Such a well-defined need or issue will allow the user group to work within a defined framework, will narrow the problem set, and will provide the management structure necessary to adopt and integrate CAPIR technology.

3.3.2 Demonstrating Cost Effectiveness

If there is a clearly defined need to adopt or use CAPIR technology, the question must be asked: Will it be cost effective to use this technology? This is a difficult question to answer. There are, however, some helpful guidelines. These are:

1. Will the data be used more than once?
2. Are all or part of our data already in digital form?
3. Do we wish to perform on-line photointerpretation directly from photography?
4. Will we be updating an existing digital map database?
5. Will we be working with HEC/SAM?
6. Will we need to obtain area and length data?
7. Will we need to perform a number of different types of analysis on the same database?
8. Will we be working with a variety of types of data (overlays)?

If the answer to any of these questions is yes, then the problem is likely to be a good candidate for using or adopting CAPIR technology.

3.3.3 Determining the Compatibility of the Infrastructure

If there is a clearly defined need and if adopting CAPIR technology is deemed cost effective, the next set of questions to be asked address the way in which this technology will fit into the infrastructure of the organization. These are important questions because they impact on both the short-term and long-term effectiveness and success of using this technology. The principal considerations relate to policy, budget, and personnel.

3.3.3.1 Policy Considerations

These considerations can be reduced to the simple question: Is the organization ready to adopt CAPIR technology? Important considerations are the existence of vested interest groups that are currently using some other technology, the psychological commitment of individuals in the organization to their current way of doing business, and the support of upper level management.

Many of these policy considerations can be ameliorated in a number of ways:

- education - short courses and seminars for both the technical and the management staff are an excellent way to smooth the introduction of new technology;
- small demonstration projects that show the utility and cost effectiveness of using the new technology;
- demonstrate the way in which the new technology can fit into current project procedures with a minimum of perturbations to the system; and
- demonstrate to others the way the new technology can help them in their own job areas.

Marketing of a new technology is extremely important to its acceptance and credibility.

3.3.4 Budgetary Considerations

The cost of technology such as CAPIR is extremely important in determining the way in which to develop an implementation plan. Questions such as "Do we have only enough money for this one project?," or "We have n-thousand dollars; where to now?" obviously affect adoption or use of CAPIR technology. Essentially, answers to these questions will determine whether work is contracted, done internally or performed through a combination of internal and contractual efforts.

3.3.5 Personnel Considerations

No matter what route an agency chooses to implement CAPIR technology, trained personnel are essential to support the effort. People who will use the technology should have a basic understanding of photo interpretation, photogrammetry, and geoprocessing. Personnel turnover rates are important, because if there is a high turnover rate, it becomes very difficult to maintain the proper support structure for new technology.

3.4 Implementation Plan

If there is a demonstrable need, a demonstrable savings in cost, and if it has been determined that the organizational infrastructure can accept the introduction of CAPIR technology, the next phase is the actual implementation of the technology. There are a number of possible routes that a group within COE could follow to implement CAPIR technology.

3.4.1 Demonstration of the Technology

One excellent method in which to introduce CAPIR technology is to perform a demonstration project at an existing CAPIR facility. This demonstration should center on a real problem and use real data and produce real, tangible, useful products. NCET's first project with COE was a demonstration project, and NCET did an excellent job. In addition, by keeping COE personnel involved on a day-to-day basis, NCET was able to convince COE personnel of the utility effectiveness and credibility of CAPIR technology. The cost of a demonstration project would probably be between 10,000 and 50,000 dollars.

3.4.2 Contracting for Services

Closely related to the demonstration project is contracting work out to a facility that has CAPIR technology. This could be another COE district office, a Federal agency, or a private firm. Contracting would be the preferred method if the group: 1) has only intermittent requirements for using CAPIR technology; 2) does not want to make the long-term capital and personnel committments to having its own CAPIR system; or 3) will never have the $350,000 to $500,000 necessary to implement CAPIR at the site.

3.4.3 Internal Processing of Contractor-Generated Data

There is an intermediate implementation method for CAPIR that lies halfway between contracting for services and having a CAPIR system on-site. This implementation involves having the digitizing and database construction contracted out but performing all the analysis and cartographic product generation on-site. This method requires that the group purchase some hardware but does not require a computer, specially trained personnel, or software. The minimum hardware configuration would consist of a graphics CRT, a plotter, a modem, and a high-speed hardcopy unit. The cost of such a configuration currently ranges between $18,000 and $40,000 depending on what hardware is purchased. The annual maintenance costs will range from $1,500 to $4,000.

3.4.4 Acquiring an On-Site CAPIR Capablity

The opposite of contracting is of course, to acquire a CAPIR system and to do all CAPIR processing on-site. This is feasible if the group has a number of long-term projects requiring CAPIR technology. Additionally, the site could become a service center for a number of COE groups.

Under this scenario, it would be necessary to purchase a complete CAPIR system similar to that described in Section 2.0. Such a system includes a host computer, tape drive, digitizing table, analytical plotter, digital plotter, graphics displays, disk drive(s), and processing software. Implementation costs currently range from $350,000 to $500,000 depending on the actual hardware/software configurations. In addition, yearly maintenance will range from $20,000 to $40,000.

This represents a major committment of funds and people over the long term. A thorough evaluation of user requirements, mandates, and goals should be performed before a commitment is made to acquire a full CAPIR capability.

3.5 CAPIR Developments and Applications for the Corps

The CAPIR system at ETL is a research and development system, and both software and hardware are in a state of constant flux. The advantage of such a system is that it can grow with technology, and new advances, such as voice recognition, can be modularly added and tested for implementation in production applications. The generality of the analytical plotter is capable of exploiting any new sensors that appear. New application packages for digital data can easily be added to the system.

3.5.1 APPS-IV Developments

It is in the use of future sensors that the generality of an analytical plotter like the APPS-IV becomes vital. The ability to handle new sensors on the APPS-IV has already been shown recently in two applications: the optical bar panoramic camera and side-looking radar imagery.

3.5.1.1 The Optical Bar Panoramic Camera Model

Panoramic aerial cameras have been available since the 19th century, but it has only been in recent years that any real effort has been devoted their routine exploitation. The basic design of the camera provides for extremely high resolution of the center lens field over the total scan angle.

One of the more successful panoramic camera designs has been the Itek KA-80-A Optical Bar Camera (OBC) system, designed for military purposes. The KA-80-A produces a panoramic image 4 1/2" by 50" in size on five-inch-wide film.

As shown in Figure 5, from a height of 60,000 ft, the ground coverage is 2.3 miles by 37 miles.

OBC imagery of large portions of the United States is available as the result of a Forest Service mapping program. Autometric has developed a mathematical model rigorously describing the dynamic imaging system of the KA-80-A, and has implemented this model on the CAPIR APPS-IV. This implementation maintains a stereo model for the operator and allows him to digitize directly from the model.

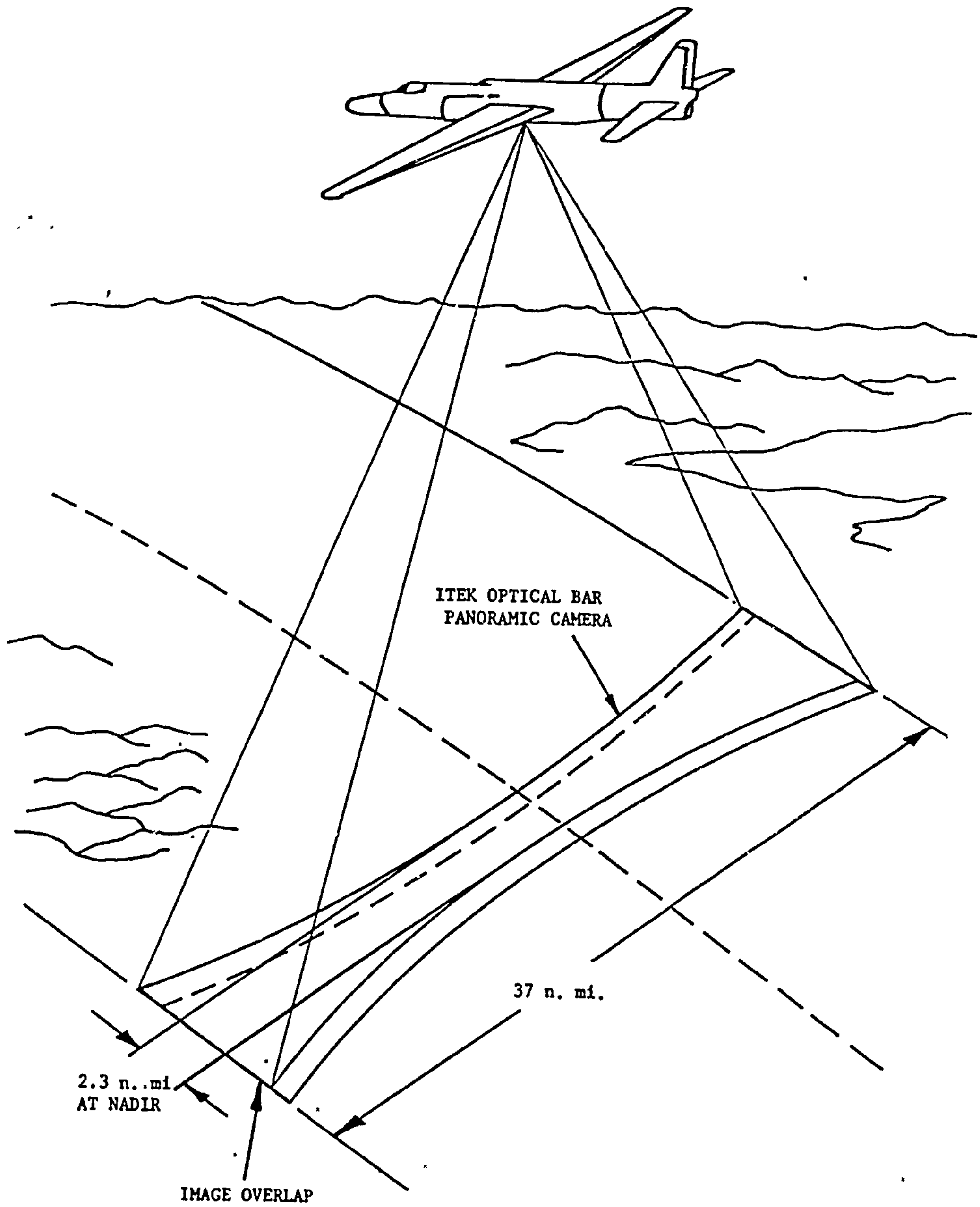


Figure 5 - Optical Bar Camera (OBC) Ground Coverage

3.5.1.2 Side-Looking Radar Model

The capability to compile from all weather Side Looking Airborne Radar (SLAR) imagery has also been added to the CAPIR system. The mathematical model is fully rigorous and is supported by an alternate set of firmware (switch selectable) in the APPS-IV. The stereo radar capability of the APPS shows great promise as a realistic means of obtaining mapping products from stereo acquisiton of SLAR imagery.

3.5.2 Future Sensors

Several new sensors are on the horizon, all of which can be exploited by CAPIR technology but not by conventional techniques. Among these sensors are SPOT, SIR-A, SIR-B, and the Large Format Camera.

3.5.2.1 System Probatoire d' Observation de la Terre (SPOT)

The SPOT satellite system will be the first of the new pushbroom scanners. Pushbroom scanning is a term that describes the technique of using the motion of a satellite platform to sweep a linear array of detectors, oriented perpendicular to the ground track, across a scene being imaged. The technique is illustrated in Figure 6.

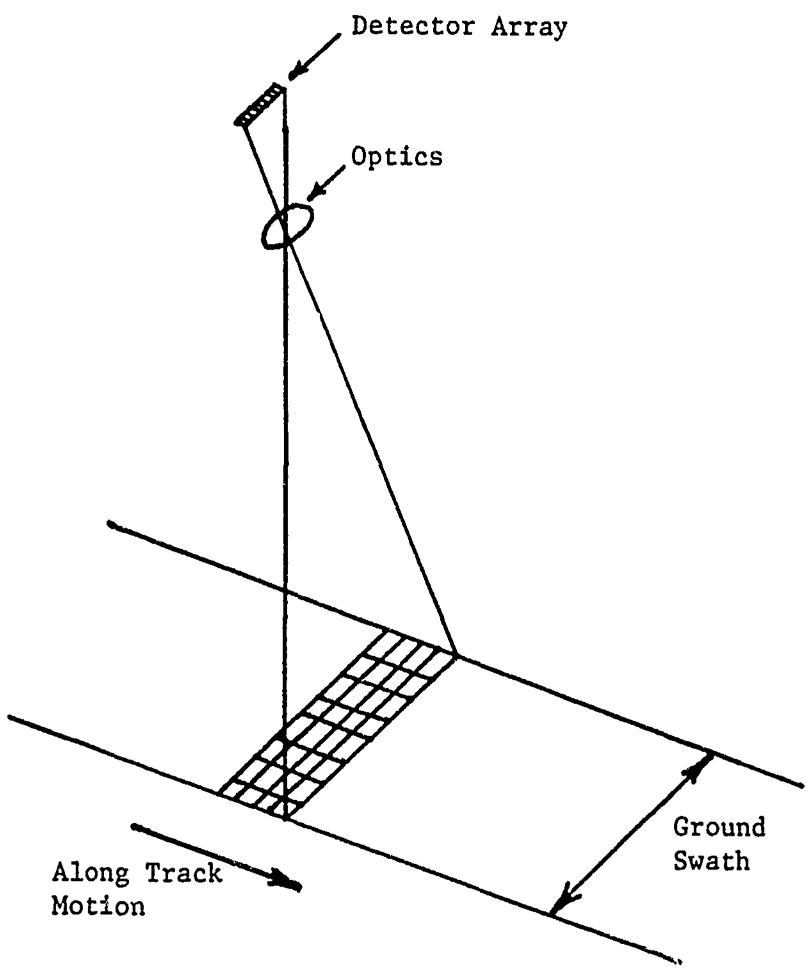


Figure 6 - Pushbroom Scanner Technique

Following its launch, projected for 1984, the SPOT will operate in either a three-band multi-spectral mode with a 20m instantaneous field of view or in panchromatic mode, with a 10m IFOV. A rotating mirror will enable a scene to be acquired from 400 km to the left or right of the spacecraft, permitting stereo data acquisition. The imaging geometry will allow elevation determination with an accuracy of 10 to 15 meters, adequate for many functions in topographic applications. SPOT, without any enhancement, would be capable of producing 1:175,000-scale map products. The projected land use assessment potential of this imagery appears impressive as does its projected capability to perform drainage basin assessment.

The APPS-IV has an accuracy of approximately 10 microns which, at the 1:400,000-scale of SPOT hard copy imagery, yields an instrumental accuracy of four meters on the ground. Since the resolution of SPOT is, at best, 10 meters, the APPS-IV figure is only four tenths of the resolution element, indicating that the measurement accuracy of the APPS-IV is entirely adequate to realize the full geometric accuracy of SPOT.

Caution will be necessary, however, in obtaining SPOT imagery for exploitation, since some of the imagery will be processed in a way that destroys its geometric properties. If the imagery has been processed, the nature of the transformations must be known so that the original imaging process can be modelled in the APPS-IV. Current literature states that SPOT imagery will be obtainable in four formats. Of these four, only correction 1A produces no geometric changes. Only Charge Coupled Detector (CCD) array photometric effects are affected by this correction.

Correction mode 1B corrects for layover. In normal photography, this process would be called rectification. It is deterministic, and could easily be removed from measured image coordinates prior to forming the projection equations used in the math model. Therefore, 1B imagery can be used easily in the APPS-IV, and in fact, the correction may improve stereo clarity.

Correction modes 2 and 3 involve the analytical warping of the imagery to fit measured control points. The warping will vary, based on the control point geometry and on errors in control point identification and measurement. It is nearly impossible to use this type of imagery in an analytical plotter.

SPOT stereo coverage will be acquired on successive passes. Undoubtedly, random error will build up over the orbital revolution, necessitating a relative orientation between the frames of a stereo pair in order to remove parallax and correct to the proper elevation datum.

The procedure would follow that used in many other applications of dynamic camera systems and would not be exceedingly complex. Because the system is a pushbroom sensor, with no camera movement during imaging, the only perturbations that must be modelled are vehicle altitude variation and flexing of the vehicle with time. The vehicle shape is short and compact (see Figure 7), which should prevent these latter effects from becoming large; they will probably exist at the random noise level only. Therefore, the mathematical model should be no more complex than for an ordinary strip camera system.

As stated earlier, the current projected launch date for SPOT is mid-1984, with the first delivery of data several months after launch. In the meantime, a simulation program will be initiated. Tentative plans are for subsidized simulation flights to begin in mid-1983, with data turnaround in approximately two-to-three months. This should give potential users a chance to assess the value of SPOT imagery for their applications.

3.5.2.2 Large Format Camera

The Large Format Camera has been built for orbital operations from the space shuttle (see Figure 8). The essential parameters of the camera itself are a 30.5-centimeter focal length and a 23-cm x 46-cm image format. Automatic exposure sensors and forward motion compensation will permit the use of high-resolution, fine-grain film. The magazine has capacity for 2400 frames.

The Large Format Camera will yield a ground resolution of approximately ten meters. With 80 percent forward overlap, a base-to-height

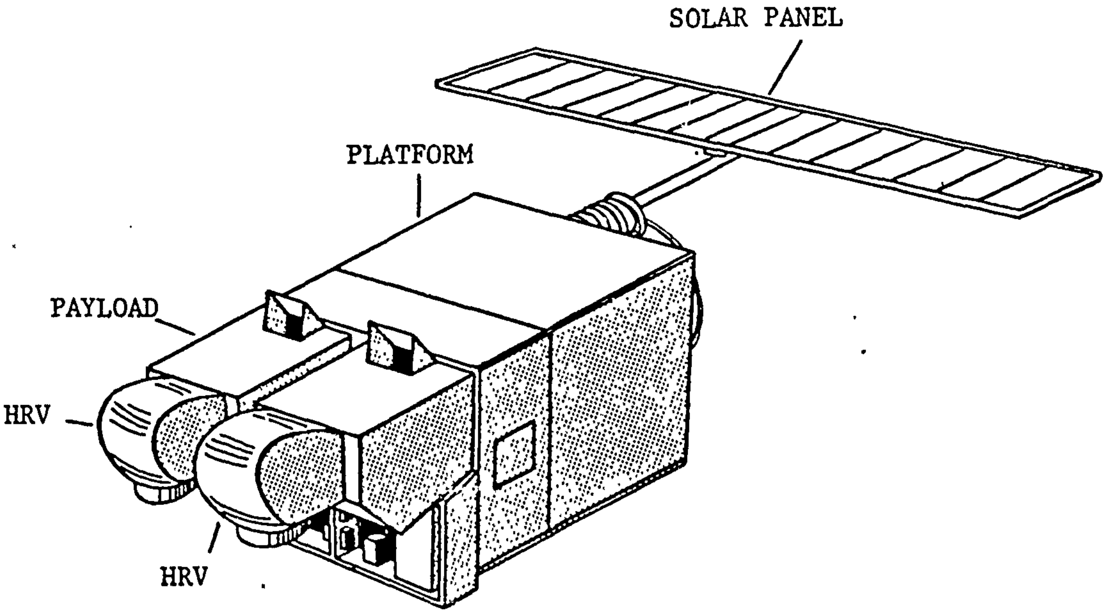


Figure 7 - The SPOT Spacecraft

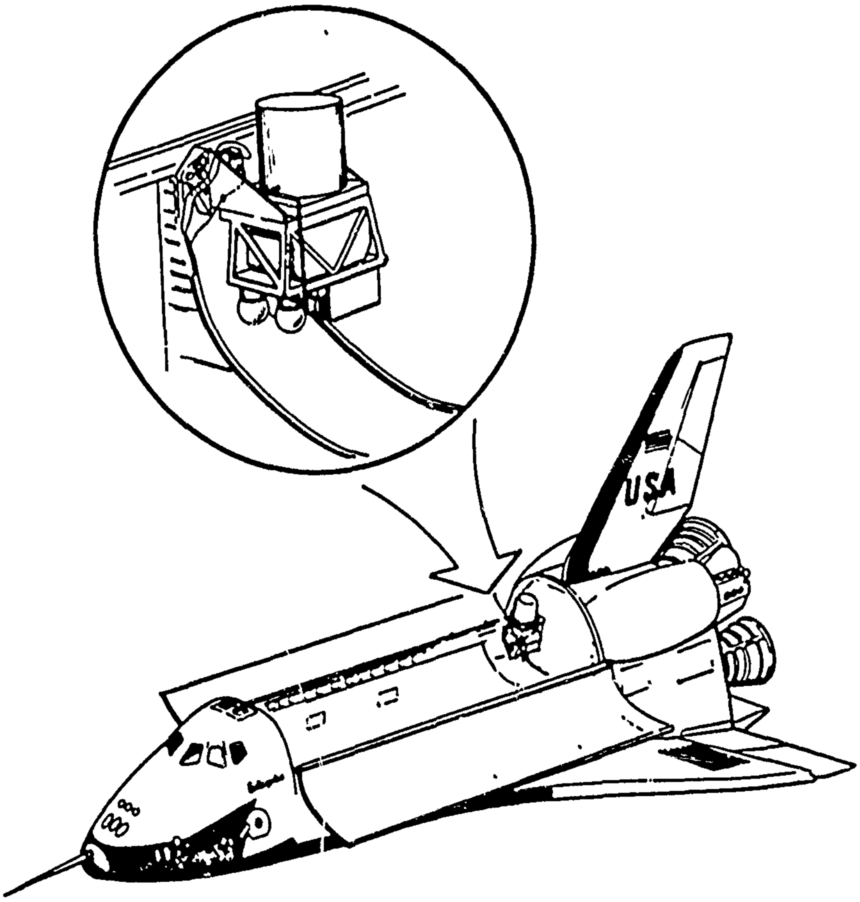


Figure 8 - Large Format Camera Deployment on the Space Shuttle

ratio of 1.2 is feasible. This camera can be flown repeatedly in the shuttle, and there are plans to image extensive areas of the world, beginning with launches from Cape Kennedy and continuing with launches into near-polar orbit from the Western Test Range.

Were it not for the wide angle of the optical system coupled with the high orbital velocity of the vehicle, the imagery could be reduced using standard analog plotters. Unfortunately, the high vehicle velocity causes Bradley aberration* to affect the position of the images on the film plane, with the net result being that the imagery is no longer strictly projective. Analog plotters, which rely upon the projective principle in their operation, cannot take maximum advantage of the potential accuracy of this imagery.

The APPS-IV, however, because it is an analytical plotter, can easily correct for the non-symmetrical aberration and can enable the imagery to be used in map compilation and data base digitization. The LFC, with its high resolution and excellent geometric accuracy, has great potential for input to Corps data bases.

Several configurations for the Large Format Camera have been suggested, including a combination of the LFC with two optical bar panoramic cameras left over from the Apollo Lunar Mapping Program. These cameras have a focal length of 610 mm, and would provide greater ground resolution than the LFC. Again, the APPS-IV would be able to correct mathematically for the distortion in this photography.

3.5.2.3 Shuttle Imaging Radar A and B (SIR-A and SIR-B)

SIR-A and SIR-B are test missions, utilizing synthetic aperture imaging radars in the bay of the space shuttle. The SIR-A mission was flown in November of 1981, and SIR-B is scheduled for launch in the future.

Orbital platforms such as the shuttle provide a very stable platform for synthetic-aperture radars, allowing the derivation of a deterministic mathematical model that can be implemented on an analytical plotter.

*Bradley aberration is a relativistic effect caused by the motion of the camera within the inertial frame of reference during the transit of the light

SIR-A and SIR-B will provide limited useful stereo coverage. However, these are only experimental systems, perhaps preceding the development of other operational civil remote sensing systems, such as the projected Canadian Radarsat and the planned Japanese SAR satellites.

It is strongly suggested that the COE consider studies of SIR-A/B imagery and of simulated SPOT and LFC imagery. These three types of data sets (especially SPOT and the Large Format Camera) appear from their specifications to have great potential application to COE projects, and the extent of their utility should be investigated in a demonstration mode over selected COE areas.

3.6 Potential Applications of CAPIR Technology in the Corps

The manifold applications of CAPIR system technology to the kinds of projects undertaken by the Corps of Engineers lie in the capability of the system to do two things:

1) to measure accurately from aerial photography and other types of imagery; and

2) to integrate and synthesize information from multiple data set sources such as remote sensing systems and thematic maps.

Some proven applications of the system in the Corps have already been discussed, and Autometric's contract with ETL will demonstrate several more. Some suggested applications are described in the following sections.

3.6.1 Watershed Studies

Accurate identification and mensuration of land use and land cover types using the APPS-IV can contribute to more accurate and reliable runoff-infiltration predictions. For example, using the analysis tools of CAPIR, land use types can be synthesized with soil types and slope categories, and in urbanizing watersheds or in areas otherwise undergoing rapid change, baseline studies of land use and land cover can be updated by visual analysis or by digital analysis of satellite imagery or satellite-acquired digital data. Some aspects of this application have been explored in Autometric's

demonstration, but, as in any research endeavor, there is more ground to be explored.

3.6.2 Erosion/Sedimentation Studies

These studies require the same information elements as are required in watershed analyses - principally soil type, land use, and slope. This information can be derived from existing maps or from remote sensing systems. Typically, space-borne imaging systems, such as the Landsat MSS and Thematic Mapper, the SPOT HRV, and the Shuttle LFC, can be use for preliminary estimates covering regional size areas, while medium- or large-scale aerial photos would be used for final estimates on smaller areas.

The use of CAPIR in tracking sedimentation in the Columbia River will be explored in the next phase of Autometric's contract with ETL.

3.6.3 Dam Site Selection

For analysis of the suitability of dam sites and their resulting impoundment basins, many types of information must be identified, measured, mapped, and synthesized with other data.

- Geologic structure - especially the location of faults and fractures. In mapping conjugate fracture sets, different line symbologies should be selected for portraying compression and extension fractures. Regional structures should be mapped using small-scale imagery, including side-looking radar from SIR-A and SIR-B if possible, followed by the analysis and mensuration of large-scale aerial photos for local structure.
- lithology - with emphasis on soluble limestone and the location of sink holes and solution channels.
- measurements of impoundment basin area and volume, including the utilization of digital elevation models.
- seismic data from published sources.
- upstream mapping of soil types, land use/cover, and topography for input to sedimentation estimation procedures.

3.6.4 Corridor Selection

Corridor selection is often necessary for pipeline, power line, and road route planning. After candidate corridors have been selected on the basis of maps and medium-scale or small-scale imagery, large-scale photography can be interpreted using the APPS-IV and analyzed for the following information:

- o cut and fill estimates
- o tree counts and size categories for clearing and grubbing estimates
- o surficial geologic mapping to locate and quantify borrow materials
- o drainage channel mapping and watershed analysis for number and size of culverts

Using the analysis capabilities of the CAPIR system, all applicable factors can be compared as an aid in selecting the optimum corridor.

3.6.5 Slope Stability Studies

Slope stability studies require elements that have been described under the topics of erosion and damsite studies, including slope steepness, land cover type, soil type, and seismicity. Additional requirements are the potential for oversteepening by stream erosion and for failure due to excess soil moisture. The three relatively constant elements, steepness, land cover, and soil type can be interpreted and measured on the APPS-IV, and the area under study can be subdivided into units, each composed of a combination of slope, cover, and soil category. Each of these units can be assigned a potential for slope failure based on some critical level of one or more of the time-variable elements, seismicity, soil moisture, and oversteeping.

3.6.6 Applications of Digital Elevation Models

As mentioned in Section 2.3.2.1.2 the APPS-IV offers an efficient means of producing Digital Elevation models. There are several other ways of producing DEM's, including field surveys and map digitization. Digital

techniques are the most effective means of manipulating the masses of data resulting from sensors such as radar or laser altimeters. Further sources of digital elevation information are the Digital Terrain tapes produced by the Defense Mapping Agency and available from the National Cartographic Information Center.

Data bases resulting from these efforts are well suited not only to the conventional application of automated generation of contour plots, but when properly processed, for a variety of end products. Some of the direct applications of DEM's are as follows:

o Profile generation — DEM's are often generated by collecting sets of profiles, but mathematical techniques can be used to generate new profiles between any pair of points in the model.

o Determination of intervisibility of points.

o Earthwork Calculations — This was one of the first applications of DEM data and is used as a routine procedure by a number of highway departments. The Portland District of the Corps of Engineers ha employed this technique for monitoring earth volume for excavation contractor payments.

o Terrain Simulation Using DEM's — Stereopairs can be produced from LANDSAT data, aiding in interpretation. The DEM data is used to compute parallaxes which would have been generated in an image made from a different exposure station. The original LANDSAT pixels are then displayed with these parallaxes to produce a simulated stereo pair aiding in visual interpretation.

3.6.7 Other Applications

Applications can be found for the CAPIR system in any endeavor involving remote sensing technology or geographic information. Numerous potential applications to Corps projects exist. If CAPIR finds effective use within the Corps, it will most likely come about through serious proper consideration of the factors detailed in Section 3.3 of this report. Interested readers can refer to Appendix B for a bibliography of more technical information about CAPIR, its components, and its applications. Autometric's contract with ETL will undoubtedly produce more useful data on the capabilities of CAPIR.

4.0 CAPIR DEMONSTRATION FOR THE DETROIT DISTRICT

Part of Autometric's study of CAPIR capabilities in Civil Works data extraction/included a demonstration data base development performed in conjunction with the Detroit District U.S. Army Corps of Engineers.

4.1 Purpose of The Detroit Demonstration

The primary use of geographic information systems within the Corps of Engineers has been in Flood Plain management studies. At the request of the Program Technical Monitor, ETL and Autometric focussed their attention on a particular ongoing study at the Detroit District and identified the assessment of potential flood damage as a possible application for CAPIR technology.

The Clinton River Basin was identified as a likely candidate for a demonstration study.

4.1.1 The Clinton River Basin

This basin is located in Southeastern Michigan (see Figure 9). The Clinton River empties into Lake St. Clair about 20 miles north of Detroit. The basin is nearly circular and has a total drainage area of 1970 square kilometers.

The upper and lower segments of the Clinton River Basin are undergoing rapid urbanization, which has a direct impact on the floodplain. The growing impermeability, resulting from an average five-year growth rate of about 3.7 percent, portends increasing problems in the future.

4.1.2 The Detroit SAM Study

The Detroit District is deeply involved in a study of the watershed, using Corps developed Spatial Analysis Methodology(SAM). Basically, the project is a planning effort, designed to determine the most efficient and cost-effective methods for alleviating flooding problems and mitigating flood damage caused by the rapid development along the Clinton River. The primary responsibilities of the planning team are to acquire data

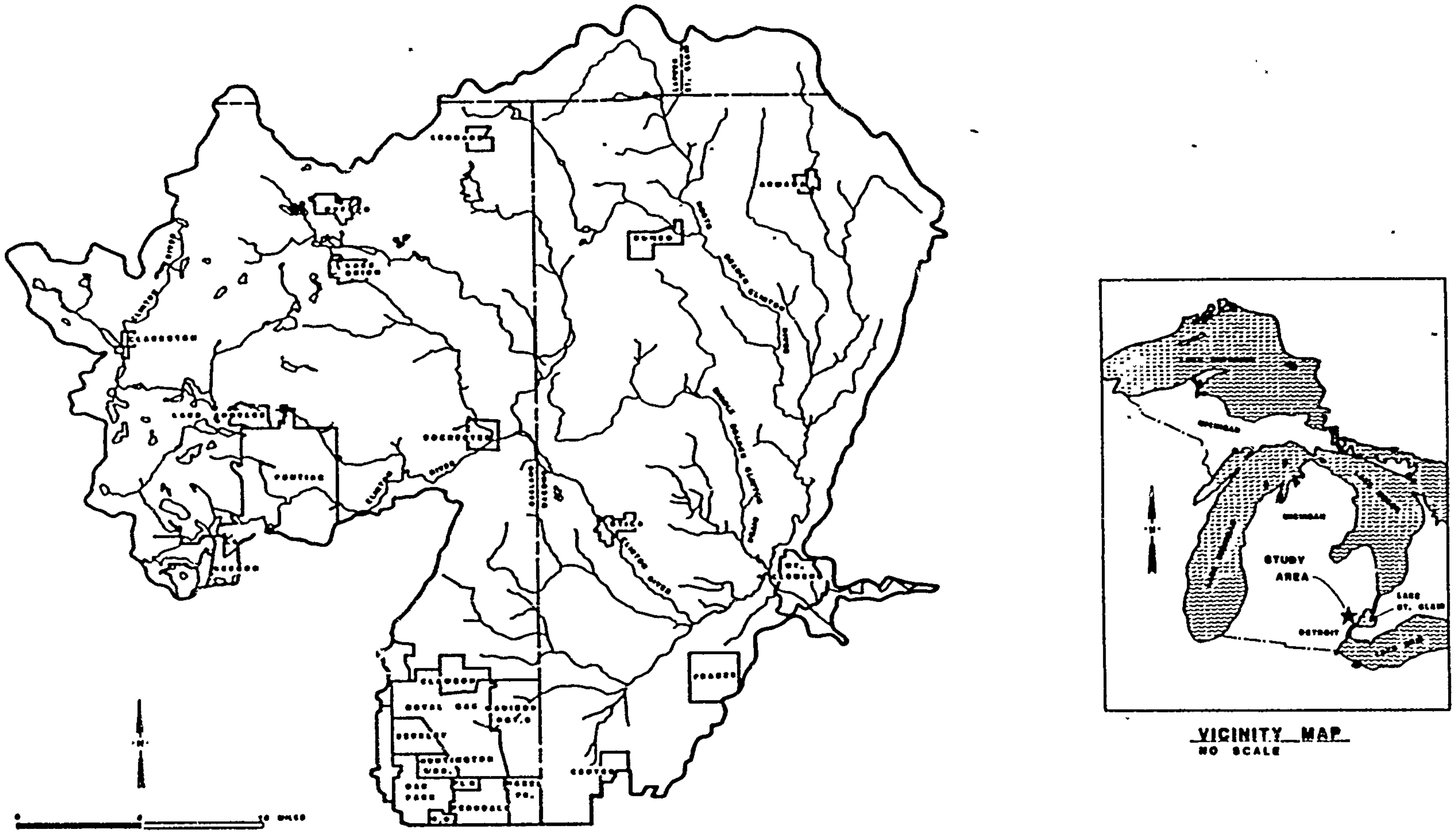


Figure 9 - Location of the Clinton River Basin

for the hydrologic forecasting and economic damage assessment models and to use these models to predict the amount of flooding that would occur and determine the amount of damage to be expected under given sets of flood conditions. The damage assessment prediction will then be compared with projected costs for building flood control structures, and a project cost/benefit ratio will be determined.

The Clinton River project is currently well under way, and all the data necessary to perform required analyses have been acquired. Most of the project is expected to be completed by the end of the current fiscal year, and there will be little involvement of planning personnel in fiscal 1983. However, a new project in the Saginaw Basin, just north of the Clinton River Basin, is scheduled to begin during fiscal 1983. The Saginaw is a large basin for which none of the data required to run the hydrologic and economic models are currently available. Consequently, district personnel are interested in using the Clinton River project to investigate various remote sensing data acquisition and data extraction techniques in order to determine the most efficient methods of acquiring the data they will need.

In discussions with Detroit personnel, Autometric and ETL have attempted to determine what data elements are most critical and difficult to obtain in their studies and to coordinate these needs with available resources so as to plan a workable demonstration.

As a result of the discussions, the geographic scope of the effort was limited to Damage Reach 12 (Sargent Creek) of Subbasin 23 in the Clinton River drainage basin. The purpose of the study was to aid in the assessment of flood damage potential.

4.1.3 Flood Damage Assessment

Flood damage assessments are performed in order to provide quantitative information on the social cost of flooding and provide a sound basis for formulating, evaluating, and implementing a range of floodplain management actions. Flood plain damage potential assessments provide a basis for identifying critical problem areas and for the development of actuarial insurance premiums. Damage estimates of potential floods can encourage local agencies and individuals to consider flood hazards in land use planning.

Flood damage assessment is accomplished by the Corps of Engineers using two approaches: An individual structure analysis of damage potential using the Corps-developed SID (Structure Inventory for Damage Analysis) computer program, and an areal analysis of damage potential using the elevation and land use of grid cells and employing the DAMCAL (Damage Calculations) program.

The SID program integrates the elevation-damage (or stage-damage) functions with hydrologic flow-frequency and flow-elevation data to compute the expected annual damage. The DAMCAL program computes a composite damage function for each land use category by assuming a number of structures per grid cell. Both computer programs then calculate aggregated elevation-damage functions by damage category and damage reach for damage reach index locations. In order to use both computer programs, the following information is required: reference structure and flood elevation data, damage potential of individual structures or for areal capture units, value of structures and contents, and damage reach delineations.

4.1.3.1 Structure Inventory for Damage (SID) Program

In the SID program stage-damage functions are developed for individual structures by damage category by computing the appropriate generalized stage percentage damage function for the specific structure. Flood stage values are referenced to elevation by equating the zero flow stage to a specific elevation. The required data to characterize each structure includes: the structure ID, damage reach assignment, reference flood elevation, stage damage function assignment, structure reference elevation, and the damage category assignment (see Figure 10). A reference flood, such as the 100-year, 500-year, etc., is used to adjust for the slope of the water surface in a particular damage reach.

The current practice in many COE offices is to inventory separately and uniquely each individual structure by flood frequency zone for flood damage computations. This is obviously a laborious process, and in light of current remote sensing and data base management techniques, probably an unnecessary one. In large planning studies dealing with thousands to tens of thousands of structures, ground structure surveys become even more inefficient and wasteful.

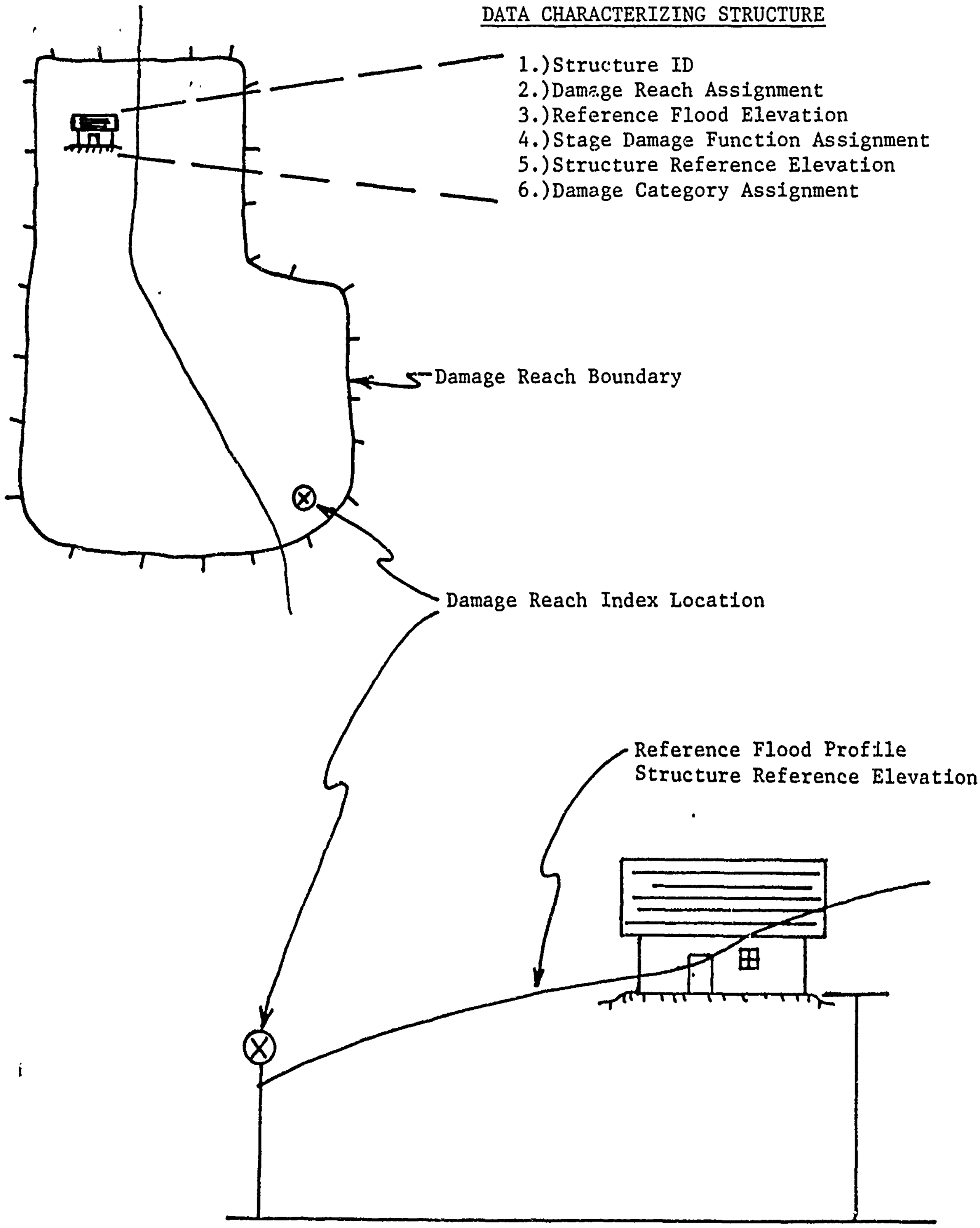


Figure 10 - Structure Data in Flood Damage Computations

4.1.3.2 Damage Calculation (DAMCAL) Program

In the DAMCAL program, spatial data variables (topographic elevation, reference flood elevation, damage reach identification, and land use patterns) are located within a geographic information system. The aggregated elevation-damage function for each damage reach location can be determined using the spatial variables. The composite damage functions can be developed for each land use category by averaging the structural and related contents value obtained from sampling a range of structure values and types within a specified category. The land use of each grid cell is determined from the geographic information system and the corresponding composite stage-damage function is determined for each grid cell. The stage is converted to elevation by equating zero stage to either ground elevation or first floor elevation. The geographic information system is accessed to determine in which damage reach the grid cell is located, and then the function is translated to the appropriate index location by adjusting the elevation axis of the damage function.

After studying these Corps techniques and data requirements, it became obvious that modern photogrammetric techniques offer an advantageous method for collecting the structure information necessary in SID. As part of the demonstration of CAPIR applications, Autometric decided to conduct a photogrammetric structure survey in support of the SID program.

The structure survey completed in support of SID can also be used to develop the composite damage functions in DAMCAL. Land use, a key factor in DAMCAL, can be interpreted and digitized using the same photography, and the analysis tools of the CAPIR system can be used to determine the averages of structure information for the separate categories.

Autometric and ETL decided to apply CAPIR to this Corps requirement as well.

4.1.4 Objective of CAPIR Demonstration

The objective of this APPS/CAPIR demonstration was to show how state-of-the-art analytical photogrammetric equipment and computer-assisted photo interpretation techniques could be used by the Corps to extract, and manipulate data required to perform flood damage assessments.

4.2 Data Collection

4.2.1 Demonstration Materials

Autometric collected a wide range of materials for demonstration use. The most important item was aerial photography and accompanying camera calibration reports. Several sets of imagery covering the Clinton River were available. The most suitable imagery, a strip of 1:30,000 color IR obtained simultaneously with NASA's Thematic Mapper Simulator data, was unusable due to an inability to locate a camera calibration report. This was also the case with a set of 1:90,000 Color IR imagery available from NASA.

The Southeast Michigan Council of Governments (SEMCOG) obtained 1:24,000 B&W imagery of the Clinton River Basin in 1980, and Autometric was successful in obtaining both imagery and USGS camera calibration reports from the contractor (Clyde E. Williams & Associates, Inc.). This SEMCOG imagery was used in the demonstration.

Autometric also obtained a large quantity of maps, USGS quadrangles and Corps of Engineer "modules", as prepared for the Corps HEC-SAM analysis. A 1:24,000 orthophoto from the USGS was also obtained. These resources served as ground control sources and as an aid to the photo interpretation.

4.2.2 Project Set-up

The first steps in beginning a job on the CAPIR system involve entering the Analytical Mapping System (AMS) and creating the project by giving it a name. The operator is led through a series of menus as he defines the location of his project and its digitization themes in the data base (Figure 11).

The themes can be compared to map overlays in a manual mapping procedure. The attributes are a breakdown of themes into smaller categories, and should represent all potential breakdowns of the theme.

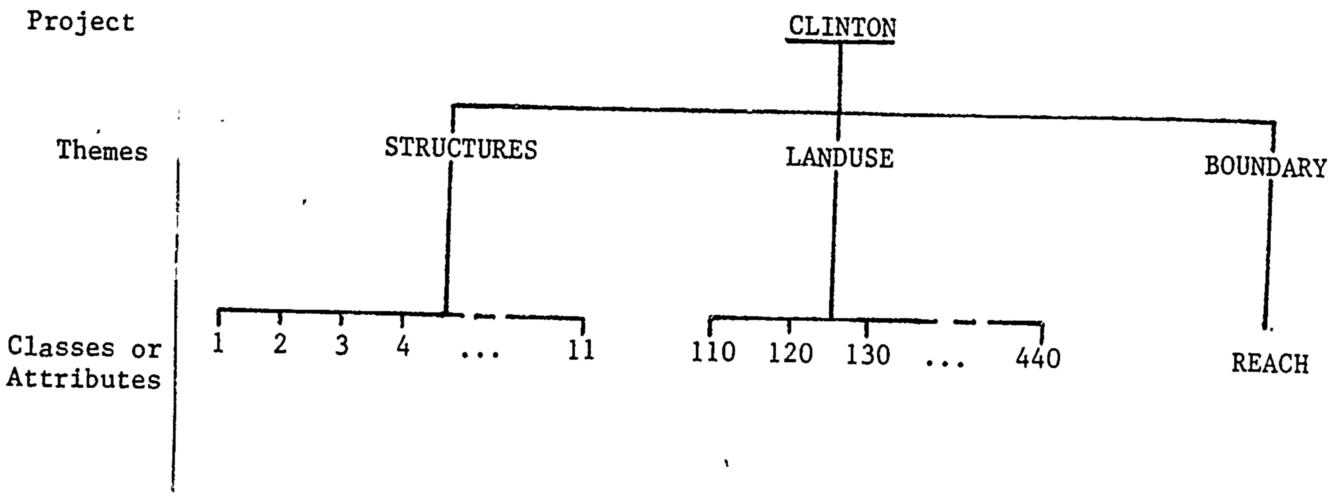


Figure 11 - AMS Data Organization

4.2.3 Aerotriangulation

Aerial photography used for digitizing purposes on CAPIR must provide stereo coverage of the area of interest. Approximately 50 to 70 percent overlap between photos is required. Before any digitizing can begin, the attitude and positions of the photographs must be determined with respect to the ground coordinate system. This process, called aerotriangulation, allows the construction of a mathematical relationship between points measured on the imagery and the geographic location of the points at the instant of exposure (See Figure 12).

The aerotriangulation process involves: (1) entering known information defining the camera interior orientation (geometry); (2) entering the geographic positions of a few control points seen in the overlapping portion of the stereo model; and (3) measuring the positions of the images of the control points on the photographs.

4.2.3.1 Preparation

In preparing for triangulation, certain steps are required before initializing the program on the CAPIR system. Initial estimates for the position and attitude of each camera station included in the triangulation

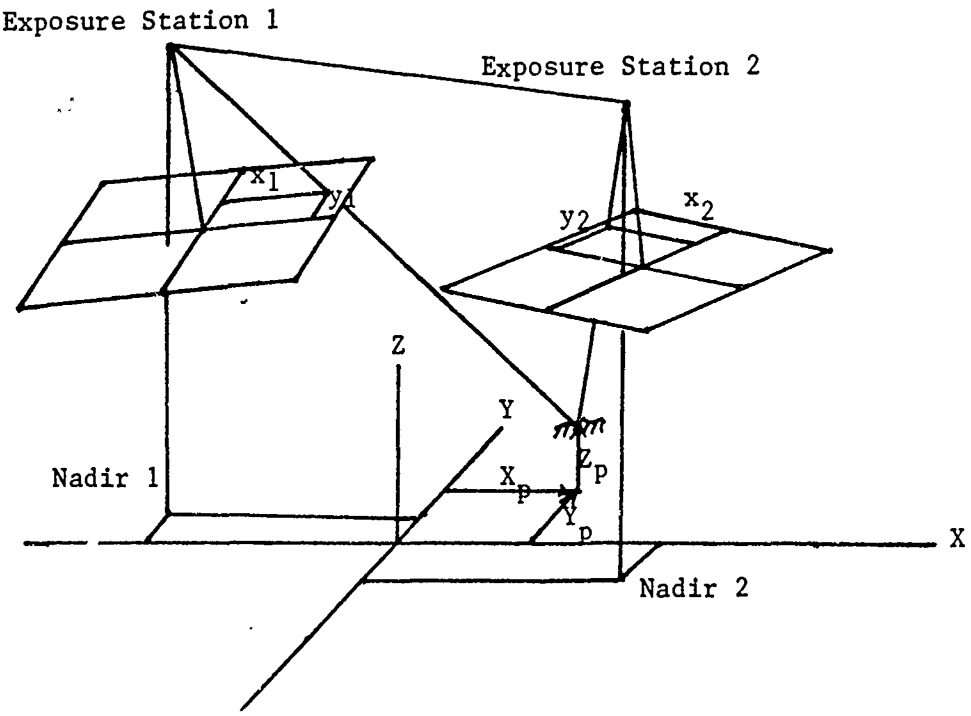


Figure 12 - Aerotriangulation

and the ground control information should be available.

The triangulation information sheet contains all information needed during a triangulation session for a particular model. Sample triangulation sheet used in the Clinton River Basin are shown in Figures (13 & 14). The first page contains information on the model and on the checkpoint (the checkpoint is a photo-identifiable point with known coordinates which must be periodically measured for quality control purposes). Further pages contain information on control points.

4.2.3.2 Ground Point Information

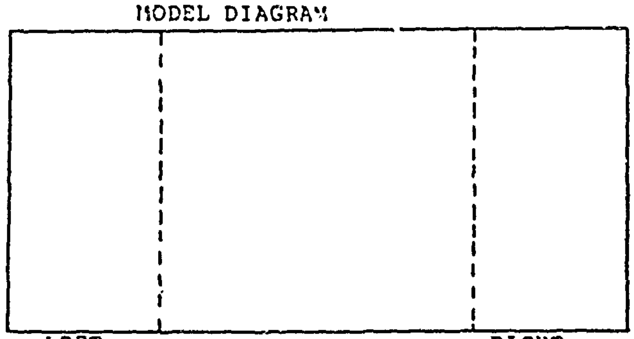
All geographic positions entered on the triangulation information sheets for the Clinton River demonstration were obtained using the digitizing table and a USGS quadrangle (Rochester).

MODEL NUMBER 1

TRIANGULATION INFORMATION

LEFT FRAME 23-10		RIGHT FRAME 23-11	
MISSION/ROLL ID	23	MISSION/ROLL ID	23
FRAME ID	10	FRAME ID	11
CAMERA ID	RCB730	CAMERA ID	RCB730
LATITUDE	42° 42' 44.641"	LATITUDE	42° 41' 33.124"
LONGITUDE	83° 12' 44.294"	LONGITUDE	83° 12' 39.770"
ELEVATION	12000'	ELEVATION	12000'
KAPPA	270-00-00	KAPPA	270-00-00
PHI	0	PHI	0
OMEGA	0	OMEGA	0

MODEL DIAGRAM



LEFT RIGHT

CHECK POINT ID 2301

DESCRIPTION

LATITUDE 42-42-37.233

LONGITUDE 83-11-04.728

ELEVATION 999.0'

H CLASS 40'

V CLASS 5'

Figure 13 - Triangulation Sheet

MODEL NUMBER 1

TRIANGULATION INFORMATION

POINT ID	2301
LATITUDE	42-42-37.233
LONGITUDE	83-11-04.728
ELEVATION	999.0
H CLASS	40'
V CLASS	5'

POINT ID	2302
LATITUDE	42-42-33.607
LONGITUDE	83-13-16.893
ELEVATION	1024.0
H CLASS	40'
V CLASS	5'

POINT ID	2303
LATITUDE	42'-41-36.313
LONGITUDE	83-13-19.146
ELEVATION	975.0
H CLASS	40'
V CLASS	5'

POINT ID	2304
LATITUDE	42-42-36.299
LONGITUDE	83-11-43.015
ELEVATION	1016.0
H CLASS	40'
V CLASS	5'

Figure 14 - Triangulation Sheet

Estimates for camera station positions were obtained by marking the center of each photograph on the quad sheet. Ground control was selected based on the ability of the operator to locate uniquely the point on both the stereo pair and on the map. As much as possible, points with marked elevations were used (e.g., road intersections).

It is possible to obtain the geographic coordinates of map points by using a utility function in AMS. The operator is prompted to measure 12 grid ticks of known coordinates around the edges of the map sheet. Using these measurements, AMS computes a polynomial transformation between x-y table coordinates and ϕ, λ geographic coordinates as projected on the map.

To ensure the validity of the transformation, the operator can review the residuals from the transformation computation and accept or reject the results.

To further ensure the validity of the results in this demonstration, four internal grid tics were measured before and after each session. Had the map shifted on the table, this check would have guaranteed that the results from that session would be discarded.

Once the operator had setup the map and measured the grid tics, he began measuring the photo centers and control points. The program requests an ID for each point measured, and prints coordinates both as they are measured (on the CRT) and at the end of the session (on the line printer).

The next step in triangulation was to enter these control point coordinates into the temporary triangulation data base. This is a manual procedure and involves merely typing in the coordinates along with an associated <u>a priori</u> indication of the reliability of the measurements. In accordance with national map accuracy standards, the sigmas on these points were initially entered as 40' horizontally and 5' vertically.

4.2.3.3 Image Measurements

Standard photogrammetric techniques were used in measuring the control point image coordinates. The images (film diapositives) were placed

on the stages of the APPS-IV and an interior orientation performed.

The interior orientation established the position of the imagery on the stages and involved identifying the model and measuring the coordinates of four reference marks (fiducials) on each image. These measurements were compared to known values (derived from the camera calibration), and a least squares fit was performed, solving for scale and rotation parameters. The statistics from each set of measurements were presented to the APPS-IV operator for review. If they were not acceptable, he performed the measurement procedure again. Generally, residuals of less than 10 microns were considered acceptable, as these approach the measurement accuracy of the APPS-IV.

When the interior orientation had been satisfactorily completed for both stages, the operator began measuring the control points. The program prompted the operator for each control point ID and directed him to measure the point. The triangulation data sheets were useful in ensuring that control points measured on the imagery had the same ID as their coordinate set in the ground control file.

This procedure was repeated successfully for the second model.

4.2.3.4 Data Edit and Review

When a full set of image measurements had been performed, the operator could have entered the triangulation solution. First, however, he reviewed the triangulation data file, which is reproduced on the next three pages. An important item in the file, and one that deserves explanation, is the "status". The presence of this variable allows the operator to "turn off" a model, image point, or ground point by setting its status to zero. When a point is turned off, it remains in the data file, but will not be used in the triangulation adjustment procedures. This technique is extremely useful in analyzing and debugging a triangulation run. Image TIE1, for example, has a status of zero on both frames. During the initial triangulation runs, this point consistently produced high residuals, probably indicating a mismeasurement of some sort. Since TIE1 was not necessary for the solution, it was "turned off".

:UDD:AMS:DATABASE:CLINTON:LINE.PRINTER

TRIANGULATION DATA FILE

DATE: 7 12 82 TIME: 10 57 55

NOTE: ALL PHOTO AND GROUND POINT POSITIONS ARE EXPRESSED IN FEET (UNLESS OTHERWISE NOTED). ALL LATITUDE. LONGITUDE COORD. AND PHOTO ATTITUDES ARE EXPRESSED IN DECREES. MINUTES. AND SECONDS. ALL IMAGE COORDINATES ARE EXPRESSED IN MICRONS.

MODEL STATUS 1 ID 1

LEFT		RIGHT	
MISSION/ROLL	24	MISSION/ROLL	24
FRAME	11	FRAME	12
CAMERA	RC8730	CAMERA	RC8730
FOCAL LENGTH	152762.000	FOCAL LENGTH	152762.000
FIDUCIAL	0 2 0 4 0 6 0 8	FIDUCIAL	0 2 0 4 0 6 0 8
LATITUDE	42 42 15.196	LATITUDE	42 41 .594
LONGITUDE	83 9 52.173	LONGITUDE	83 9 49.813
ELEVATION	12000.000	ELEVATION	12000.000
SIGMA	5000.00	SIGMA	5000.00
OMEGA	0 0 .000	OMEGA	0 0 .000
PHI	0 0 .000	PHI	0 0 .000
KAPPA	269 59 59.806	KAPPA	269 59 59.806
SIGMA	10.0000000	SIGMA	10.0000000

IMAGE 2401 STATUS 1

LX	43003.	LY	-67596.
RX	-51852.	RY	-66160.

IMAGE TIE1 STATUS 0

LX	17292.	LY	-63774.
RX	-77119.	RY	-62085.

IMAGE 2402 STATUS 1

LX	42350.	LY	34869.
RX	-51311.	RY	35728.

IMAGE 2403 STATUS 1

LX	105625.	LY	35397.
RX	11085.	RY	35466.

```
:UDD:AMS:DATABASE:CLINTON:LINE.PRINTER


IMAGE  2404                    STATUS  1
   LX     105682.     LY        -11112.
   RX      10960.     RY        -10706.


                            MODEL STATUS  1      ID   2
LEFT                                                  RIGHT
MISSION/ROLL          23                              MISSION/ROLL          23
FRAME            10                                   FRAME            11
CAMERA          RC8730                                CAMERA          RC8730
FOCAL LENGTH 152762.000                               FOCAL LENGTH 152762.000
FIDUCIAL       0  2  0  4  0  6  0  8                 FIDUCIAL       0  2  0  4  0  6  0  8
LATITUDE      42 42 43.989                            LATITUDE      42 41 32.989
LONGITUDE     83 12 43.901                            LONGITUDE     83 12 38.983
ELEVATION       12000.000                             ELEVATION       12000.000
SIGMA           5000.00                               SIGMA           5000.00
OMEGA           0  0    .000                          OMEGA           0  0    .000
PHI             0  0    .000                          PHI             0  0    .000
KAPPA         269 59 59.806                           KAPPA         269 59 59.806
SIGMA         10.0000000                              SIGMA         10.0000000

IMAGE  2301                    STATUS  1
   LX      17039.     LY         93652.
   RX     -79911.     RY         92444.


IMAGE  2302                    STATUS  1
   LX      17215.     LY        -32471.
   RX     -81328.     RY        -33871.


IMAGE  2303                    STATUS  1
   LX      89749.     LY        -36927.
   RX      -7785.     RY        -38609.


IMAGE  2304                    STATUS  0
   LX      17194.     LY         57095.
   RX     -80293.     RY         55781.


IMAGE  TIE1                    STATUS  0
   LX      63988.     LY         95411.
   RX     -32097.     RY         94196.


IMAGE  2401                    STATUS  1
   LX      89351.     LY         91735.
   RX      -6704.     RY         90684.
```

:UDD:AMS:DATABASE:CLINTON:LINE.PRINTER

```
GROUND  2301                STATUS  1
   LATITUDE     42   42   37.233              SIGMA       50.FT
   LONGITUDE    83   11    4.728              SIGMA       50.FT
   ELEVATION       999.000  FT                SIGMA       10.FT

GROUND  2302                STATUS  1
   LATITUDE     42   42   33.607              SIGMA       40.FT
   LONGITUDE    83   13   16.893              SIGMA       40.FT
   ELEVATION      1024.000  FT                SIGMA        5.FT

GROUND  2303                STATUS  1
   LATITUDE     42   41   36.313              SIGMA       40.FT
   LONGITUDE    83   13   19.146              SIGMA       40.FT
   ELEVATION       975.000  FT                SIGMA        5.FT

GROUND  2304                STATUS  0
   LATITUDE     42   42   36.299              SIGMA       40.FT
   LONGITUDE    83   11   43.015              SIGMA       40.FT
   ELEVATION      1016.000  FT                SIGMA       10.FT

GROUND  2401                STATUS  1
   LATITUDE     42   41   39.829              SIGMA       40.FT
   LONGITUDE    83   11    2.366              SIGMA       40.FT
   ELEVATION       956.000  FT                SIGMA        5.FT

GROUND  2402                STATUS  1
   LATITUDE     42   41   42.576              SIGMA       40.FT
   LONGITUDE    83    9   14.260              SIGMA       40.FT
   ELEVATION       856.000  FT                SIGMA        5.FT

GROUND  2403                STATUS  1
   LATITUDE     42   40   53.577              SIGMA       40.FT
   LONGITUDE    83    9   12.283              SIGMA       40.FT
   ELEVATION       824.000  FT                SIGMA        5.FT

GROUND  2404                STATUS  1
   LATITUDE     42   40   52.368              SIGMA       40.FT
   LONGITUDE    83   10    1.172              SIGMA       40.FT
   ELEVATION       846.000  FT                SIGMA        5.FT
```

4.2.3.5 The Aerotriangulation Solution

In the Clinton River triangulation, each model was adjusted separately and checked for blunders before a simultaneous adjustment of both models was attempted. As problems were found, the data edit and review procedure was performed to correct them. Several points were remeasured, necessitating the re-setup of the stereo models. Other problems included the unaccountable loss of an entire, working triangulation data file, forcing the operator to start the procedure from the beginning.

The final solution is shown in the following four pages. The solution coverged in three iterations and all the residuals appear acceptable.

:UDO:AMS:DATABASE:CLINTON:LINE.PRINTER

ITERATION # 1

P H O T O G R A M M E T R I C   R E S I D U A L S

	IMAGE	M/R	FRAME	CAMERA NO.	X	Y
**	2301	23	10	21	7559.469	-9160.125
**	2301	23	11	21	10476.560	-5276.312
**	2302	23	10	21	2587.898	1814.023
**	2302	23	11	21	4149.437	5533.031
**	2303	23	10	21	-5174.500	-458.207
**	2303	23	11	21	-3068.148	2956.410
**	2401	24	11	21	-6544.031	4992.625
**	2401	24	12	21	3156.133	8945.937
**	2401	23	10	21	-461.313	-13132.440
**	2401	23	11	21	2943.227	-9112.750
**	2402	24	11	21	-2863.316	-3867.820
**	2402	24	12	21	7051.117	-541.352
**	2403	24	11	21	-7226.062	-5285.891
**	2403	24	12	21	1477.547	-2756.445
**	2404	24	11	21	-9123.062	-1879.871
**	2404	24	12	21	-375.324	1003.652

ITERATION # 2

P H O T O G R A M M E T R I C   R E S I D U A L S

	IMAGE	M/R	FRAME	CAMERA NO.	X	Y
**	2301	23	10	21	735.820	-367.375
**	2301	23	11	21	838.688	-258.688
**	2302	23	10	21	334.957	390.020
**	2302	23	11	21	317.000	474.242
**	2303	23	10	21	-193.375	195.852
**	2303	23	11	21	-164.723	263.766
**	2401	24	11	21	-627.902	143.313
**	2401	24	12	21	30.941	603.188
**	2401	23	10	21	163.063	-761.813
**	2401	23	11	21	300.484	-601.875
**	2402	24	11	21	-307.563	-442.016
**	2402	24	12	21	304.285	-95.863
**	2403	24	11	21	-529.313	-500.277
**	2403	24	12	21	-81.562	-239.781
**	2404	24	11	21	-696.375	-325.832

:UDD:AMS:DATABASE:CLINTON:LINE.PRINTER

**	2404	24	12	21	-212.074	-6.680

ITERATION # 3

P H O T O G R A M M E T R I C   R E S I D U A L S

	IMAGE	M/R	FRAME	CAMERA NO.	X	Y
**	2301	23	10	21	4.566	2.000
**	2301	23	11	21	4.938	.813
**	2302	23	10	21	2.422	5.551
**	2302	23	11	21	1.063	2.895
**	2303	23	10	21	-.500	3.313
**	2303	23	11	21	-1.855	2.613
**	2401	24	11	21	-4.488	-3.938
**	2401	24	12	21	-2.266	.250
**	2401	23	10	21	2.375	-1.250
**	2401	23	11	21	1.461	-1.813
**	2402	24	11	21	-1.527	-4.316
**	2402	24	12	21	-.762	-2.773
**	2403	24	11	21	-.938	-3.836
**	2403	24	12	21	-2.180	-3.227
**	2404	24	11	21	-2.375	-4.316
**	2404	24	12	21	-2.922	-2.898

*** TRIANGULATION PROCESSING SYSTEM SOLUTION ***

AUTOMETRIC INCORPORATED

DATE: 7 12 82 TIME: 10 47 55

NOTE: ALL PHOTO AND GROUND POINT POSITIONS ARE EXPRESSED IN FEET (UNLESS OTHERWISE NOTED). ALL LATITUDE. LONGITUDE COORD. AND PHOTO ATTITUDES ARE EXPRESSED IN DEGREES. MINUTES. AND SECONDS. ALL IMAGE COORDINATES ARE EXPRESSED IN MICRONS.

*** SOLUTION CONVERGED IN 3 ITERATIONS ***

*** LOCAL TANGENT ORIGIN ***
LAMBDA -83 12 44.000

```
:UDD:AMS:DATABASE:CLINTON:LINE.PRINTER

                         PHI          42  42 44.000



          *** MISSION/ROLL 23        FRAME 10   CAMERA NO.      21 ***

          COMPUTED     RESIDUAL                COMPUTED          RESIDUAL
   XC     -151.48      -158.89      KAPPA   272 13   12.70     2 13   12.90
   YC      477.01       478.13      PHI       0 44    3.58     0 44    3.58
   ZC    12961.62       961.63      OMEGA     0 35   10.00     0 35   10.00

                              *** PHOTO RESIDUALS ***

                              ID          X         Y
                              2301        0.        0.
                              2302        0.        0.
                              2303        0.       -1.
                              2401        0.        0.

          *** MISSION/ROLL 23        FRAME 11   CAMERA NO.      21 ***

          COMPUTED     RESIDUAL                COMPUTED          RESIDUAL
   XC      250.70      -124.20      KAPPA   272 20   48.28     2 20   48.47
   YC    -7267.88       -74.81      PHI       0 47   39.50     0 47   39.50
   ZC    12978.35       979.59      OMEGA     0 10   53.27     0 10   53.27

                              *** PHOTO RESIDUALS ***

                              ID          X         Y
                              2301        1.        0.
                              2302        0.       -1.
                              2303       -1.        0.
                              2401        0.        0.

          *** MISSION/ROLL 24        FRAME 11   CAMERA NO.      21 ***

          COMPUTED     RESIDUAL                COMPUTED          RESIDUAL
   XC    13111.44       273.91      KAPPA   271 19    5.42     1 19    5.67
   YC    -3118.28      -204.15      PHI       1 14   39.45     1 14   39.45
   ZC    12958.18       962.31      OMEGA     0 45   52.64     0 45   52.64

                              *** PHOTO RESIDUALS ***

                              ID          X         Y
```

:UDD:AMS:DATABASE:CLINTON:LINE.PRINTER

2401	0.	0.
2402	0.	0.
2403	0.	0.
2404	0.	0.

*** MISSION/ROLL 24 FRAME 12 CAMERA NO. 21 ***

	COMPUTED	RESIDUAL		COMPUTED	RESIDUAL
XC	13132.48	114.26	KAPPA	272 5 47.35	2 5 47.54
YC	-10614.12	-143.27	PHI	0 42 45.29	0 42 45.29
ZC	12932.21	938.88	OMEGA	1 1 41.75	1 1 41.75

*** PHOTO RESIDUALS ***

ID	X	Y
2401	0.	0.
2402	0.	0.
2403	0.	0.
2404	0.	0.

*** GROUND POINT PARAMETERS AND RESIDUALS ***

ID	X	Y	Z	DX	DY	DZ
2301	7450.09	-704.28	997.48	37.88	-20.38	-.20
2302	-2478.76	-1085.85	1023.88	-22.74	-33.77	.04
2303	-2628.91	-6820.62	973.67	-4.00	32.01	-.04
2401	7586.62	-6479.73	953.66	-3.88	15.81	.04
2402	15666.85	-6222.05	849.22	2.77	-8.79	-.00
2403	15814.79	-11169.55	815.05	-.37	4.30	.01
2404	12167.23	-11295.04	839.41	3.98	3.47	.00

*** CHECK POINT ID'S ***

MODEL			ID	
24	11	24	12	2401
23	10	23	11	2301

***

4.2.4 Photogrammetric Structure Survey

As explained in Section 4.1.3, the use of photogrammetry in structure surveys appeared to extend great advantage to the Corps. The results could ideally be used in both the SID and the DAMCAL programs.

4.2.4.1 Detroit District Practices

SID and DAMCAL require the input of different structure information. Conversations with Detroit District personnel revealed that techniques for gathering structure information varied, depending upon whether SID or DAMCAL would be run.

SID requires a 100 percent structure breakdown of an area. This is generally accomplished by ground survey techniques and is obviously a labor intensive practice.

DAMCAL employs an aggregate structure figure, which is developed by averaging structure density in land use categories. The 1980 SEMCOG land use classifications provided some guideline, and these densities were verified by on-site ground checking. Structure elevations were derived from five and ten foot USGS contours.

The same structure type breakdown was used for both SID and DAMCAL; it is shown in Table 1.

TABLE 1 - Structure Breakdown

CODE(ATTRIBUTE)	STRUCTURE TYPE
1	1 STORY, NO BASEMENT
2	1 STORY WITH BASEMENT
3	2 STORY, NO BASEMENT
4	2 STORY WITH BASEMENT
5	SPLIT LEVEL, NO BASEMENT
6	SPLIT LEVEL WITH BASEMENT
7	MOBILE HOME
8	SMALL/MEDIUM COMMERCIAL
9	LARGE COMMERCIAL
10	HEAVY INDUSTRIAL
11	PUBLIC

4.2.4.2 Software Development for Detroit Demonstration

When Autometric personnel began to plan the structure survey, it was immediately obvious that a minor software development would be tremendously useful. The Damage Reach boundary is an artificial boundary and cannot be discerned on the photography. The Sargent Creek area is densely developed with a large number of structures. Without some means of delineating the damage reach boundary, the APPS-IV operator would probably expend much labor digitizing structures that do not fall within the damage reach.

Graphic Superposition offers an ideal method for marking this damage reach boundary. Existing AMS software, however, offered the capability to display only one theme. It was impossible to display boundaries and structures. Software to view ancillary information was developed in the course of this contract and added to the CAPIR system.

4.2.4.3 Digitization of Structures

The actual digitization of the structures in the damage reach took place over a three-day period, a three hour session on the first two days and a one hour session on the third.

The survey involved identifying the structure type, placing the floating dot on the ground immediately in front of the structure, and measuring the point. After the measurement, the structure was tagged with a green spot on the graphic superposition, display, relieving the stereoplotter operator of the necessity of keeping track of the structures he had measured.

There were 634 structures in the damage reach. The summary report produced by AMS follows. The survey was a tedious task but could be simplified by slight software modification and the use of voice data entry.

Several problems were apparent in the structure survey and they probably affected the accuracy of the data. One obvious problem was the use of the presence or absence of a basement as a classification criteria. Since this structure survey was performed using vertical aerial photography, basements were impossible to detect. In the Detroit area, most buildings have

basements, but in many areas, this generalization does not hold. There is no apparent solution to this problem in CAPIR data collection, and any resolution would have to come from the HEC-SAM analysis procedures.

The categories used in classification presented other problems. Some structures did not appear to fit well into any category. Detroit District personnel informed Autometric that apartment buildings should fit into the "small/medium commercial" category, but other structure types were relatively undefined. Rows of townhouses, for example, could be classified as apartments or as two story buildings. Buildings under construction were also a problem, as their eventual size and function was impossible to determine. Partial tree cover on the building sites compounded the problem.

Autometric was unable to assess how critical these problems are to Corps requirements due to relative unfamiliarity with damage potential assessment procedures. Corps personnel will have to consider the problems. However, analytical photogrammetry appears to offer a reasonable and vastly cheaper alternative to ground surveys. At the very least, photogrammetry could be used to perform the basic survey, which would then be supplemented by a selective ground survey of problem areas.

4.2.4.4 Accuracy of Structure Elevations

The accuracy of the results obtainable through photogrammetric means will depend upon the imagery, the ground control, and the stereo measurement device.

There is a direct relationship between the scale of photography and the accuracy of measurements obtainable from it. Photographic scale is approximately equal to camera focal length divided by height above terrain, and therefore, it can be increased by decreasing the flying height.

Photogrammetric results cannot be more accurate than the ground control used in the aerotriangulation. Surveyed ground control will be much more accurate than map control; its use is generally preferable but will be influenced by economic factors.

Accuracy requirements will be a factor in any photomission

planning or consideration of existing imagery. Larger-scale photography implies the need to use a greater number of photographs, thereby increasing cost. Labor costs for ground survey crews are much more expensive than the costs of obtaining USGS quads and locating points appearing on both map and photo. These tradeoffs, familiar to photogrammetrists, must all be considered whenever Corps districts consider using photogrammetry and photo interpretation.

4.2.5 Land Use Interpretation

Land use is a key factor in HEC/SAM analysis. It is used as the primary indicator of development status, and many analytical methods use it to forecast the hydrologic, economic, and environmental consequences of existing and alternative future development patterns.

Because of this critical land use focus, the Corps has given special attention to the development and use of a reasonable set of land use categories. The criteria applied to determine a rational set of land use categories include compatibility with local agency classification systems, potential for automatic classification by use of remote sensing technology, and responsiveness to technical requirements. Table 2 shows the land use categories selected by the Detroit District for analysis of the Clinton River Basin.

TABLE 2

1980 SEMCOG Land Use Categories

Land Use Type	Code Used by Code
Aquatic Open Space	
Wooded Wetland	110
Open Wetland	120
Water	130
Terrestrial Open Space	
Woodland	210
Brushland	220
Grassland	230
Agricultural	
Active Cropland	300
Cultural	
Residential	410
Residential - Multi-Family	411
Residential - Moderate and High Density Single Family	412
Residential - Low Density Single Family	413
Railroads	421
Roads	422
Institutional/Industrial/Commercial	430
Extractive/Barren	440
Additional Autometric Classification	
Institutional	431
Industrial	432
Commercial	433

4.2.5.1 Land Use Mapping Techniques Used in the Detroit Study

The Corps acquired its Clinton River land use data from 1980 land use maps compiled by the South East Michigan Council of Governments (SEMCOG). These data were developed at an extremely fine level of detail and required editing, consolidation, and remapping prior to digitization.

The reformatting of the SEMCOG maps was accomplished in several steps. First, collateral information such as aerial photography, existing maps, and ground survey data was collected to assist in clarifying and refining the land use designations on the SEMCOG manuscripts. Mylar overlays were registered to base maps. Pertinent delineations were transcribed from the SEMCOG data maps defining homogeneous land use types. Features identifiable on the base maps, such as roads, structures, water bodies, etc., were used as reference locations to insure consistency in the mapping of the SEMCOG and supplementary data onto the overlays.

Polygon drafting took the form of a series of connected straight line segments rather than curved lines, and polygon delineations were restricted to a 10-acre minimum in order to facilitate conversion to the anticipated grid cell size. Polygons having boundaries consisting of more than 300 vertices were broken into two or more polygons. As each polygon was delineated, the three-digit land use code was labeled at its center.

Once all the polygons and codes were drafted, they were edited first by the Corps and then by the contractor. The Corps' edit involved edge-matching adjacent maps to ensure line and code consistency and continuity. The contractor subjected the maps to a final pre-automation edit and repaired minor discrepancies such as graphic mistakes.

After the mapping procedure was completed, the data were prepared for automated processing. The three primary activities in this preparation process were: 1) assignment of polygon sequence numbers, 2) labeling of intersections, and 3) delineation of the formal study area boundary. Each prepared map was then machine encoded.

Each modular land use data file was then individually processed

and graphically edited prior to conversion to a grid cell file structure. The processing steps consisted of executing a series of reformatting programs and of correcting code and coordinate inconsistencies in the data.

This processing attempted to remove sliver, overlap, and intersection mis-tie problems in the data. Discrepancies were handled either by redigitizing or by manual modification of coordinates.

Once finished, the land use data were plotted and subjected to final edit. An additional program merged several files to create PIOS (Polygon Information Overlay System) files, a necessary step in grid cell generation.

Grid cell generation consisted of first converting reference point coordinates to Michigan State Plane Coordinates using a USGS-supplied routine. All digitized polygon coordinates (in units of inches) were then changed to Michigan State Plane coordinates using a bilinear transformation between reference point coordinates in inches and the state plane coordinates in feet for the same point.

All land use files were then concatenated, and the final polygon file was converted to a 10-acre grid cell file. The resultant single variable file consisted of a row and column offset from the origin and a land use code, based on the predominant land use in the cell.

4.2.5.2 Photo Interpretation Techniques Used in Autometric's Demonstration

The Detroit District indicated to Autometric that the categories used in the SEMCOG procedures were sufficient for all damage calculations, but that they would be interested in the ability of the CAPIR system to further break down category 430 (Institutional, Industrial, Commercial). This proved difficult without the use of ancillary data, but the interpreter made the attempt, and the Institutional, Industral, and Commercial areas were assigned codes of 431, 432, and 433 respectively.

The labor expended in the land use interpretation consisted of the identification of the correct photography, registration of Mylar overlays to the photography, and manual delineation of land use boundaries.

It was necessary to first delineate the land use boundaries on the mylar because of incomplete features in the AMS digitizing software. As explained in Section 2, AMS uses the arc-node scheme in digitizing. Current software does not allow an operator to "drop" a node into an arc after he has digitized it. Therefore, he must mark all nodes as they are encountered. This makes simultaneous interpretation and digitization difficult, and production facilities have adapted the practice used in this demonstration: rough interpretation at photo scale on an overlay followed by precise, three dimensional digitization on the APPS-IV, refining the lines on the overlay.

The node "dropping" capability is a scheduled augmentation of the AMS software and will rectify this problem.

The SEMCOG photography used in this demonstration was interpreted using a Zeiss reflecting mirror stereoscope, a light table, and a hand magnifier. The interpretation was not a complicated task, but the interpreter noted that the effort was somewhat tedious.

4.2.5.3 Digitization on the APPS-IV

The mylar overlay was registed to one of the photos in the stereo pair covering most of the damage reach, and the photos were slipped onto the stages of the APPS-IV. After an interior orientation, the photos were ready for digitization.

Actual digitization of the overlay took place over two days. The operator was familiar with the APPS-IV but unfamiliar with the AMS digitization procedues. Operation of the system, however, is easy to learn, and after very little time, digitization proceeded at a regular pace.

Since there were slight registration and scale errors in the overlay, and since the stereo model is three dimensional and the overlay is two dimensional, the actual digitization did not precisely follow the penciled lines on the overlay. Instead, the operator attempted to determine what the boundary between categories was, and followed that naturally occurring line while keeping the floating dot on the ground so as to remove completely the effects of relief displacement.

Unfortunately, the entire damage reach did not fit onto one stereo model. The spur on the western edge projected into another model. This model was successfully triangulated early in the demonstration in anaticipation of its use.

At some point, however, between the aerotriangulation and the digitization, the photography apparently underwent some sort of non-linear distortion, for it proved impossible to perform an acceptable interior orientation and reset the model. Thus it was impossible to digitize from this model, and the end of the spur was ignored in the demonstration. It would have been possible to obtain imagery and re-triangulate, but due to time constraints, this was not done.

After all the land use polygons on the working stereo model had been digitized, an attempt was made to "verify" the data. Verification is a fully automated procedure that ensures that all data are topologically valid before they are output.

The verification process is carried out in several steps. The first step is the deletion of previously verified features that contain a segment that has been deleted or an attribute that has changed since the last attempt at verification. The file of deleted segments contains a list of these segments.

The second step of verification involves the checking of the nodes for various conditions. Basically, any normal node (not an edge or temporary node) must have at least three line segments associated with it unless certain conditions prevail. If only one segment enters, then this segment must be one that enters a polygon, and it must have two side attributes and a center attribute. An example of such a segment would be a stream entering but not passing through a polygon.

In the case of two segments entering a node, one of two conditions can prevail. The segments can both be a part of a simple loop, in which case both segment identifiers will be identical. The second case is a loop that, for some reason, is broken by a temporary node. In this case, both segments entering the node must terminate on temporary nodes. Any node having two or fewer entries that does not satisfy one of the above conditions is in

error, and an appropriate error message will be displayed on the operator's console.

Because certain special conditions pertain to those features that contain edge nodes, they are verified first. The edge nodes are first sorted (starting at the northwest corner of the geounit and proceeding in a clockwise manner). Next, the formation of the features is begun. Each edge node is used in turn, and the feature that is on the right as one leaves the edge of the geounit is verified. If there is a left attribute, it will be used when a later feature closes on that edge node. One type of error, therefore, is the case of a left attribute that never gets used. If this error occurs, an appropriate error message will be displayed on the operator's console, and the edge node involved can be highlighted on the graphics display to aid in the correction of the error.

The other errors that can occur, both in the edge node feature verification and in the normal node feature verification, take the form of errors that occur at nodes, which prevent the program from deciding which segment it should use to leave the node. In all of these cases, an error message is displayed, and the segment near the node can be highlighted on the grahics display to guide the user to the problem. When errors in verification occur, an error message is displayed and program control returns to the digitizing monitor.

Data editing proved to be a tedious process in the demonstration effort. Most errors resulted from the use of an operator who was initially unaccustomed to the AMS digitization procedures. Approximately two days were spent on data verification, far longer than would be necessary with trained personnel. (Production facilities using AMS have little trouble with passing through verification.) When the land use map was verified, it was entered into the data base. The AMS report follows

.UJV.AYC:DATABASE:CLINTON:LANDUSE:SUMMARY.FILE

ROCHESTER

TOTAL NUMBER OF POLYGONS IN GEOUNIT 120
TOTAL NUMBER OF ATTRIBUTES IN GEOUNIT 11
TOTAL ACREAGE FOR ATTRIBUTES 885.08[illegible]

ATTRIBUTE	NUMBER	ACRES	PER CENT
412	9	246.166	27.81
411	3	15.046	1.70
230	25	87.362	9.87
435	6	41.098	4.64
300	7	110.366	12.47
413	13	91.695	10.36
220	12	59.200	6.69
210	31	147.264	16.64
240	9	[illegible]	[illegible]
431	[illegible]	7.677	.87
130	4	7.910	.89

4.3 Map Overlay and Analysis

4.3.1 Data Transfer

Data collected using the Analytical Mapping System had to be transferred to the Map Overlay and Statistical System for analysis and conversion to ESRI HEC-SAM format.

During the transfer process, the coordinate data were transformed from Latitude/Longitude to Universal Transverse Mercator. (Once in the MOSS data base, the data can be transformed to many other projective coordinate systems, including all the state plane systems.) The transfer process builds a map data set in form suitable for quick query, retrieval, display and analysis.

Three of the digitized maps were transferred from AMS to MOSS: 1) the study area boundary, 2) the structures, and 3) the landuse. The total database for the Clinton study contained 740 features, defined by over 10,000 coordinate pairs and requiring 350,000 characters of storage (in MOSS format).

4.3.2 Data Checking/Review

Once the data were transferred, a MOSS selection by attribute by map was performed. This allowed MOSS to plot each attribute as a single display map. Figures 15 to 19 are for the structure data and Figures 20 to 23 are for the landuse data. These simple plots by attribute are done for a number of reasons:

1. They allow the user to determine the spatial distribution of each variable, i.e., land use type or structure type;
2. They allow the user to become more familiar with the map data;
3. They allow the user to perform a last visual check of the validity of the data; i.e., are there any gross digitizing errors, spikes, or missing data.

Most groups using AUTOGIS for project work create these plots and keep them in project notebooks for future reference.

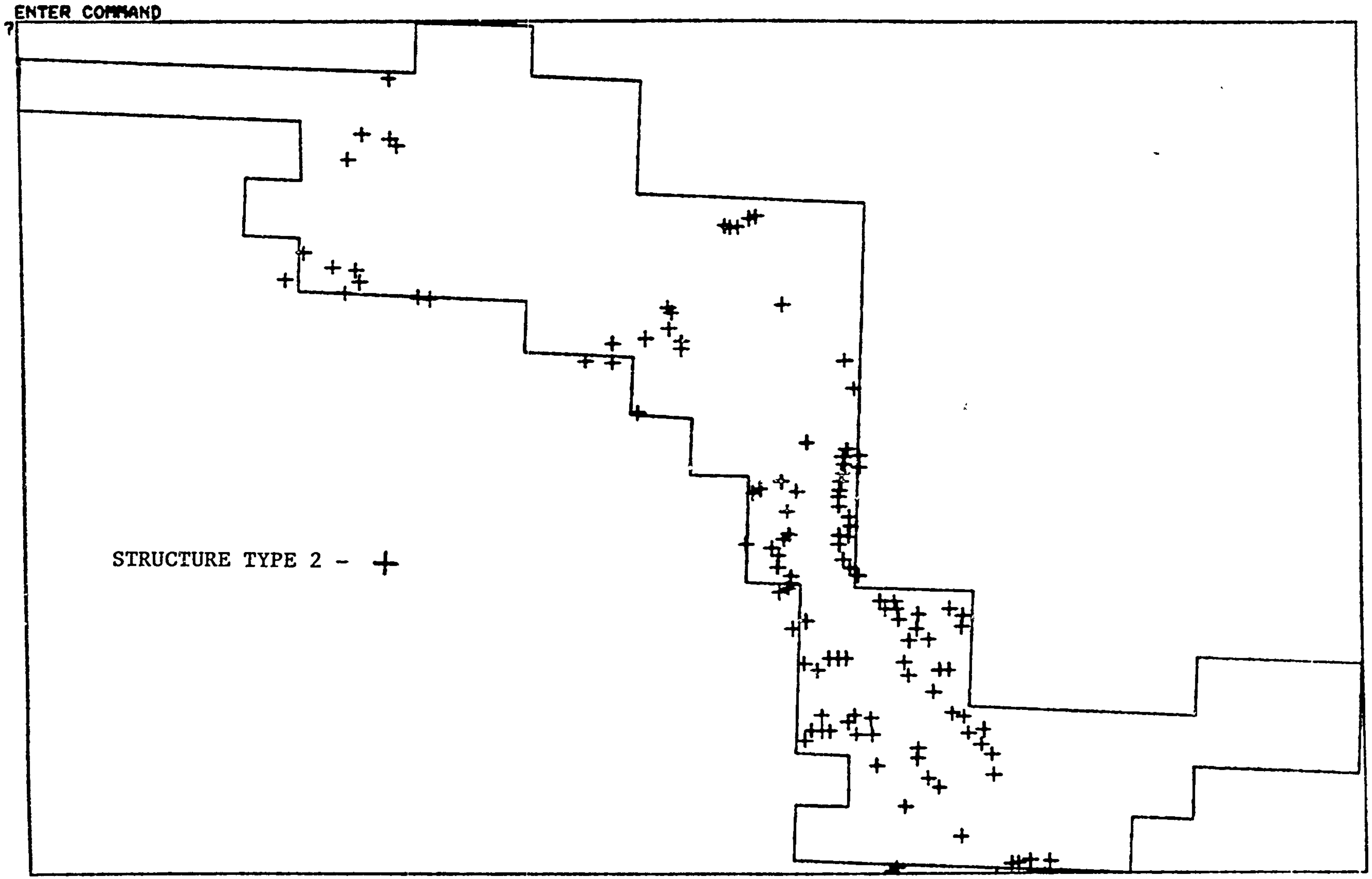


Figure 15 - MOSS Plot of Structure Type 2

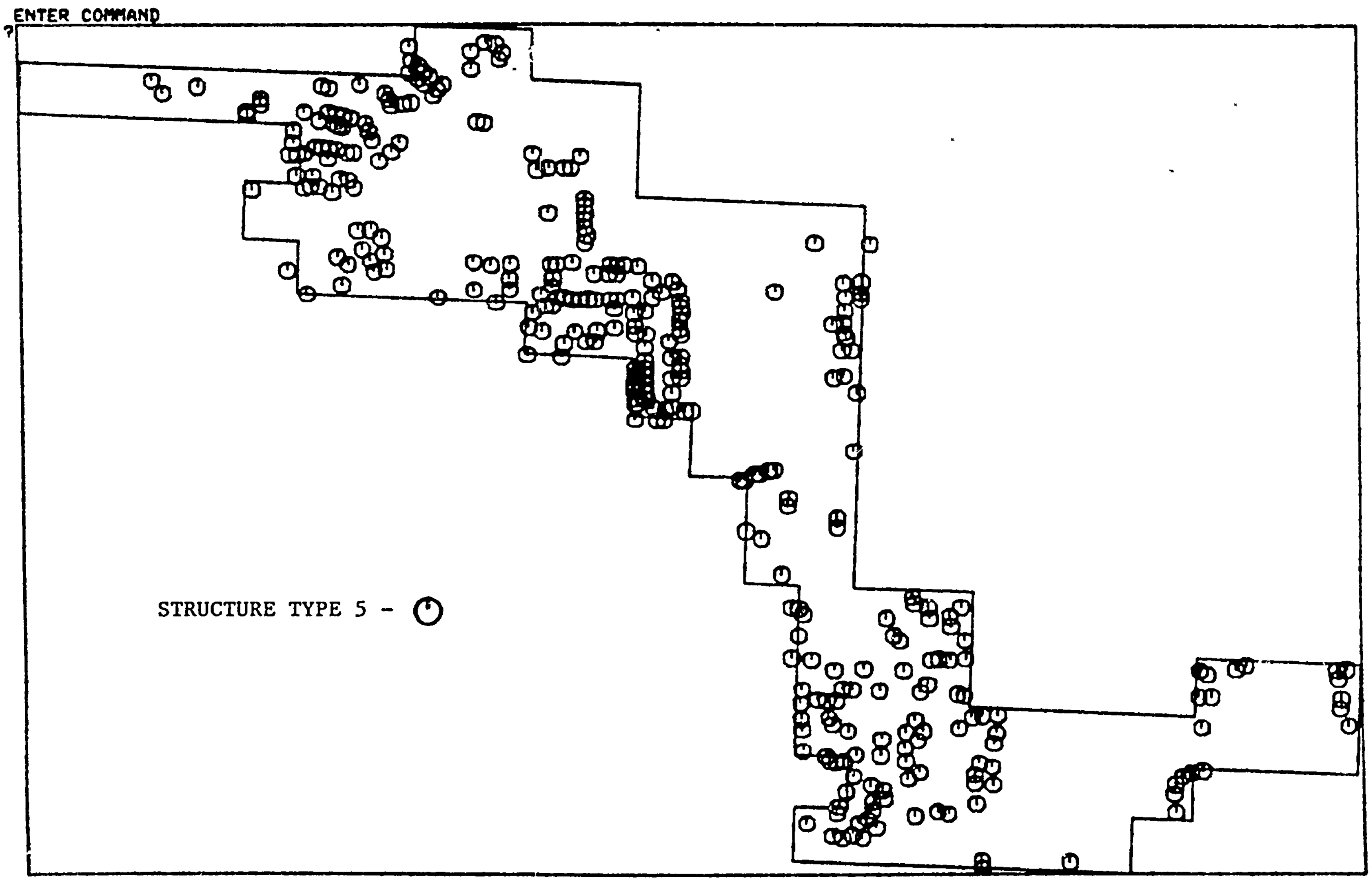


Figure 16 - MOSS Plot of Structure Type 5

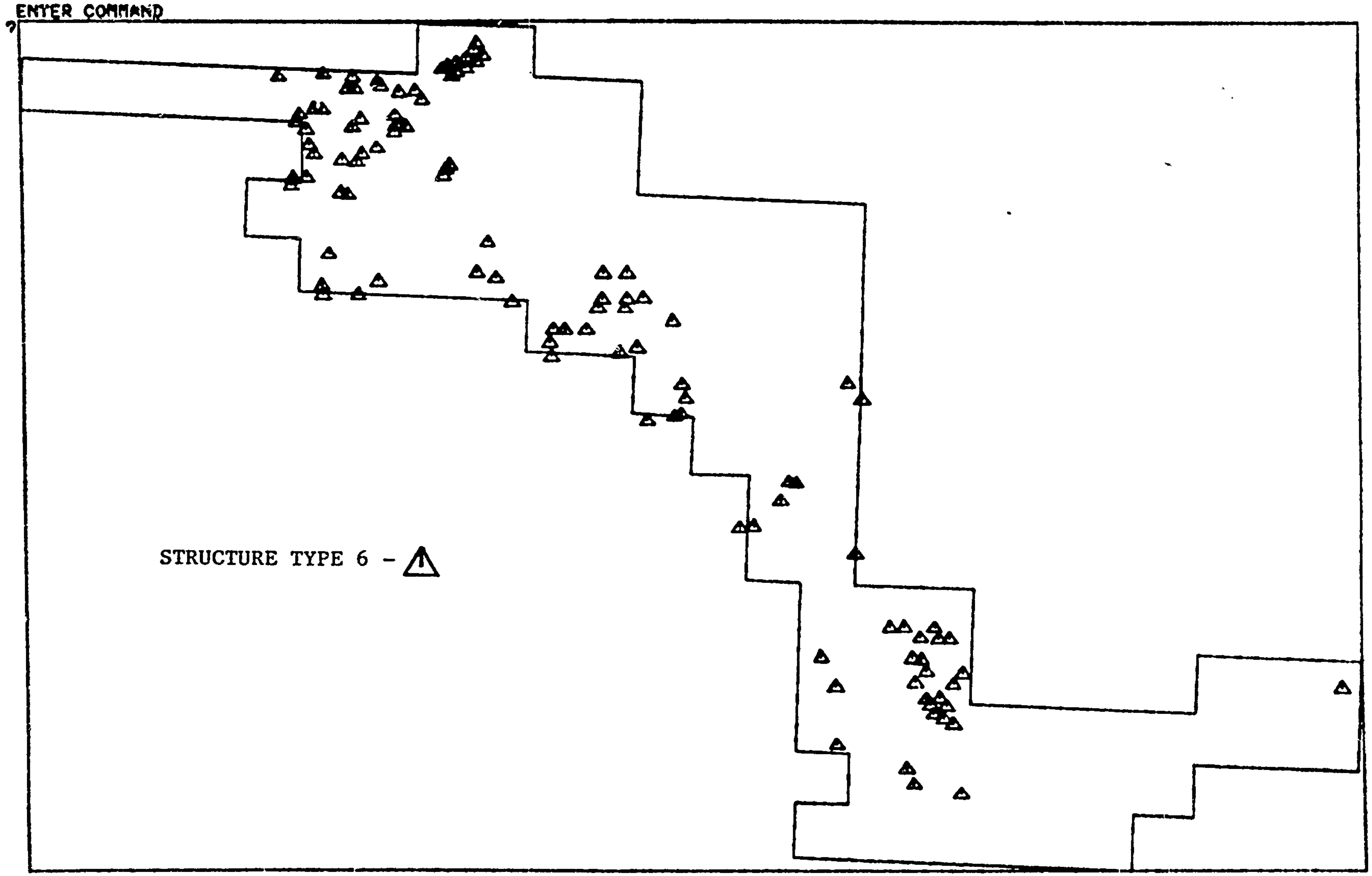


Figure 17 - MOSS Plot of Structure Type 6

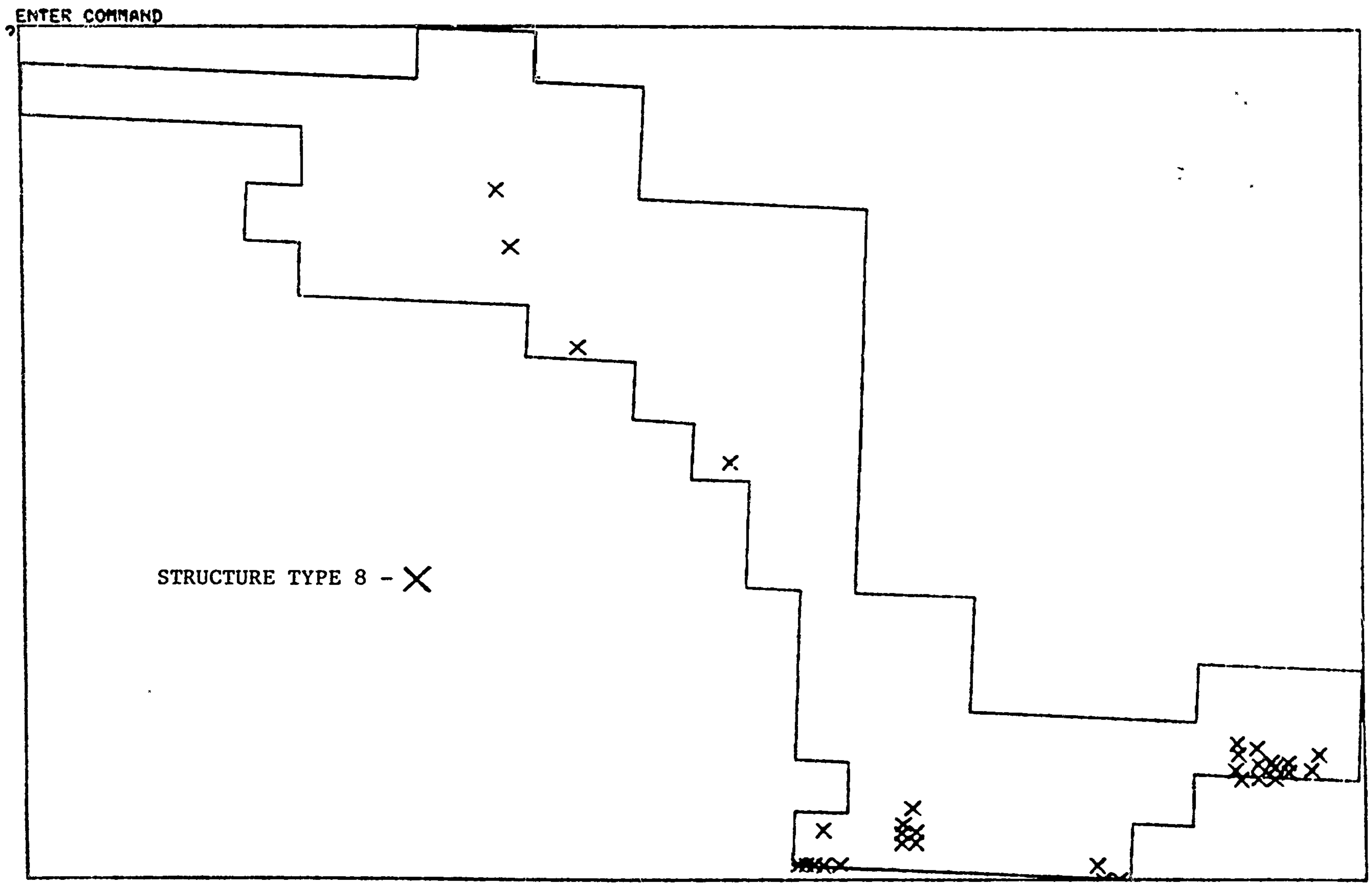


Figure 18 - MOSS Plot of Structure Type 8

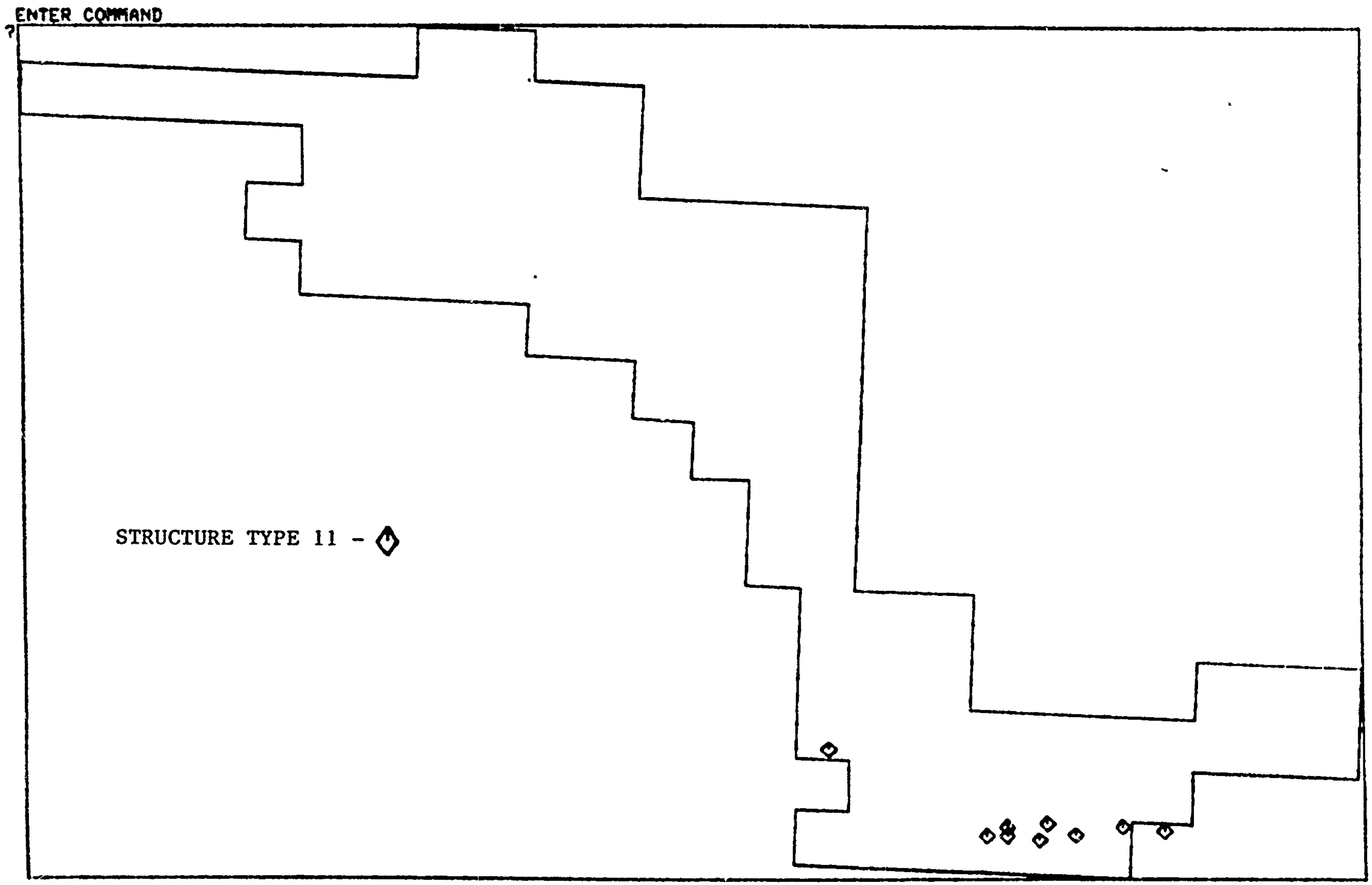


Figure 19 - MOSS Plot of Structure Type 11

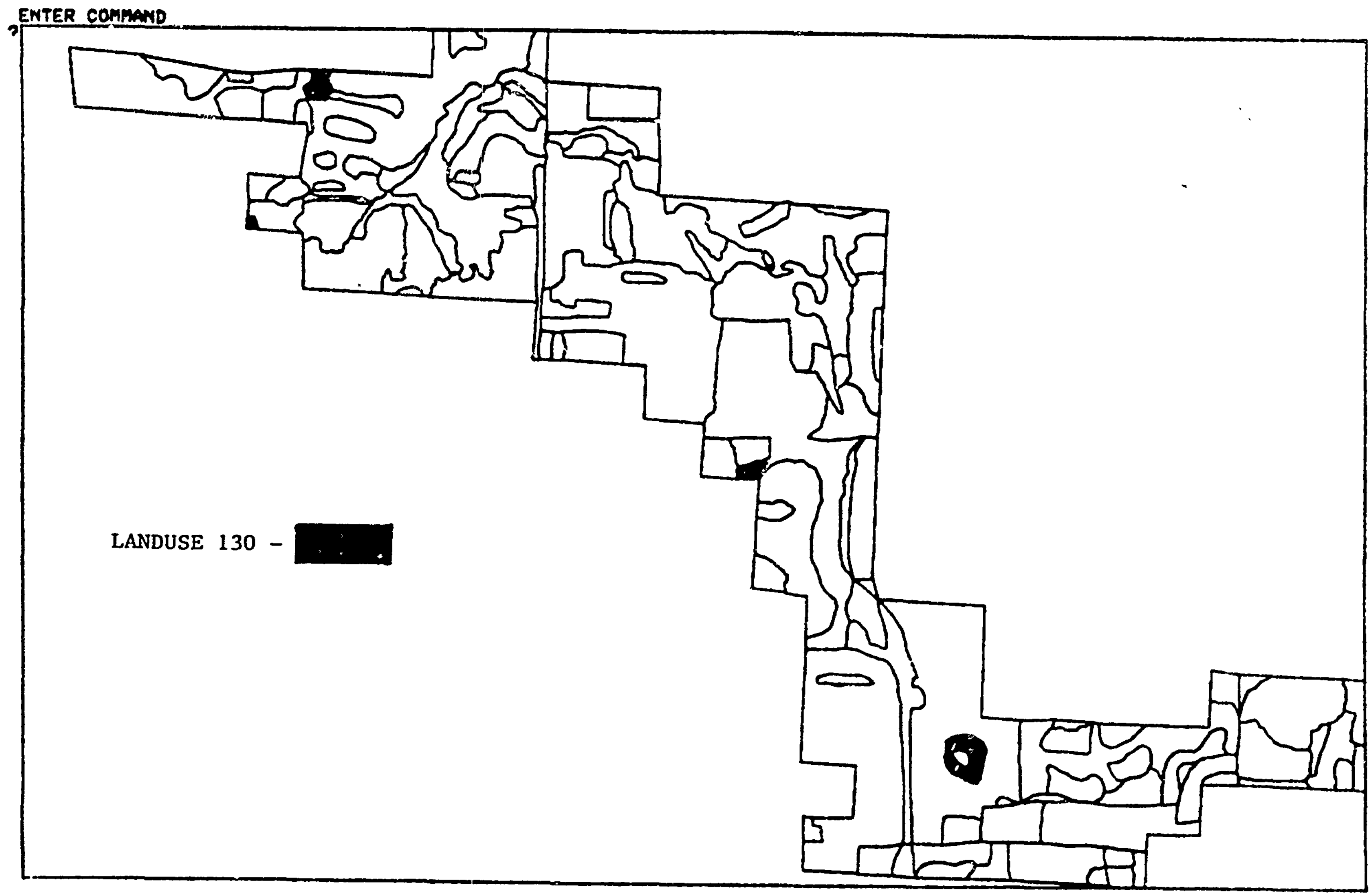


Figure 20 - MOSS Plot of Landuse 130

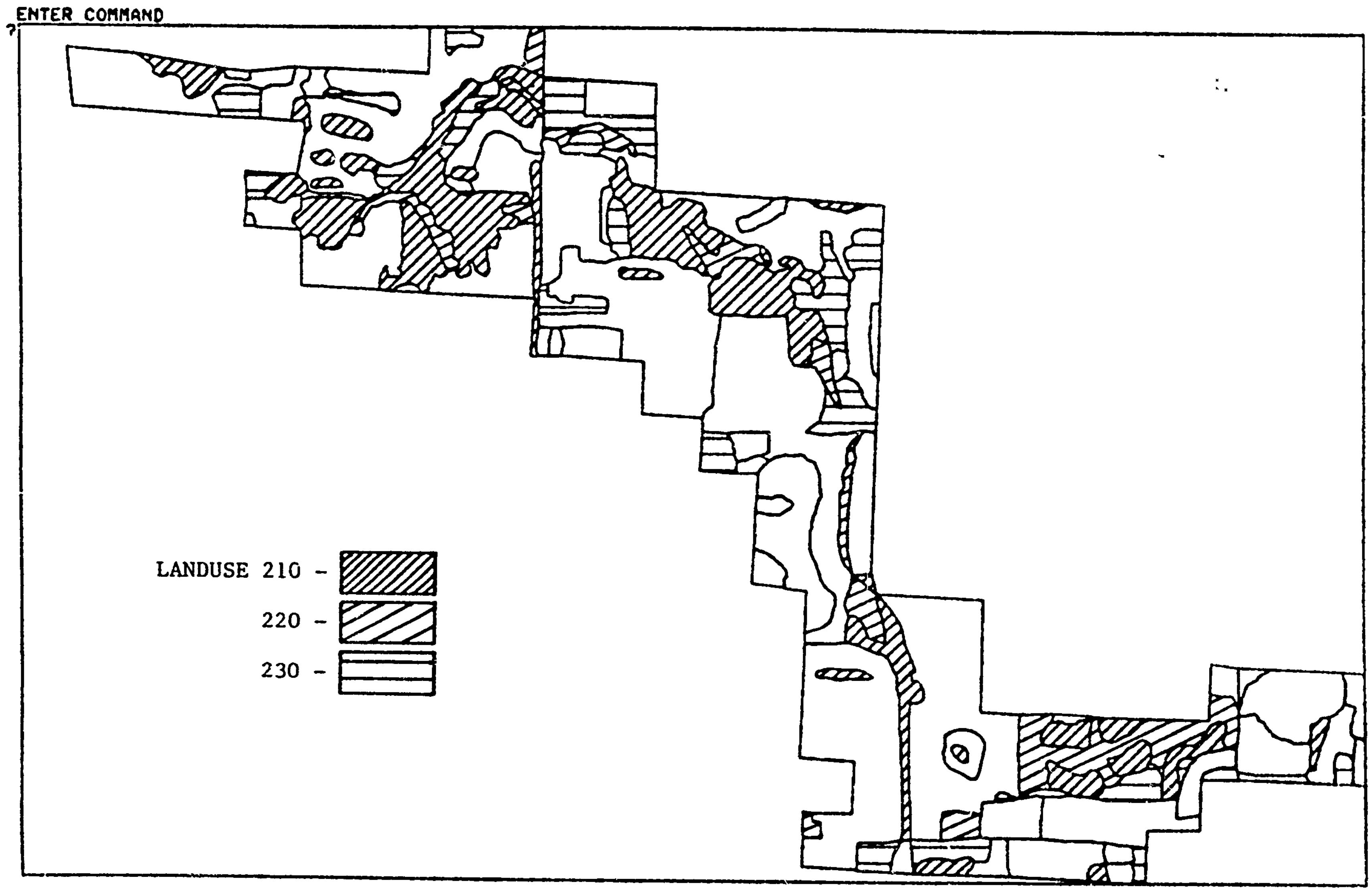


Figure 21 - MOSS Plot of Landuse 210, 220, 230

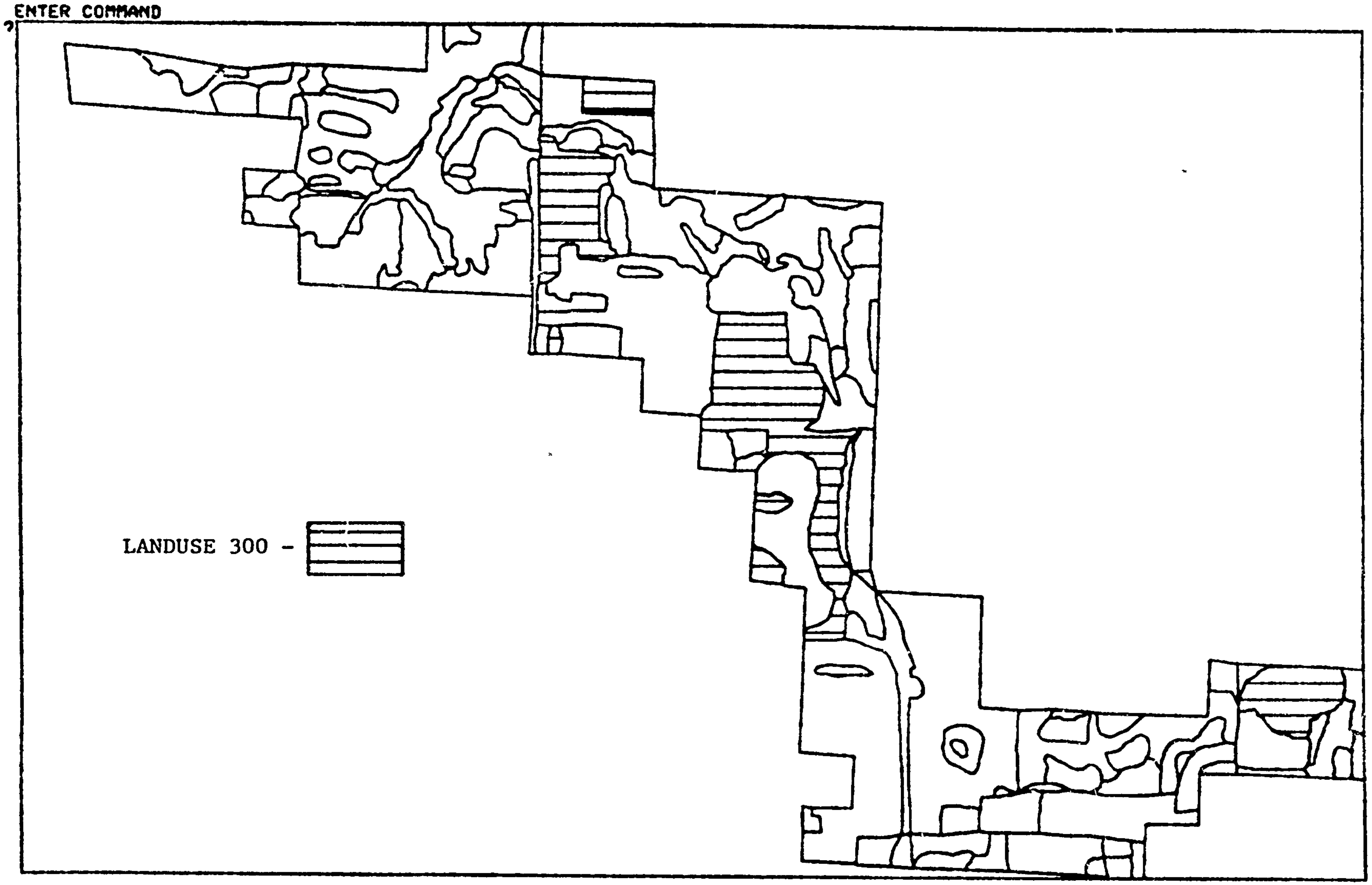


Figure 22 - MOSS Plot of Landuse 300

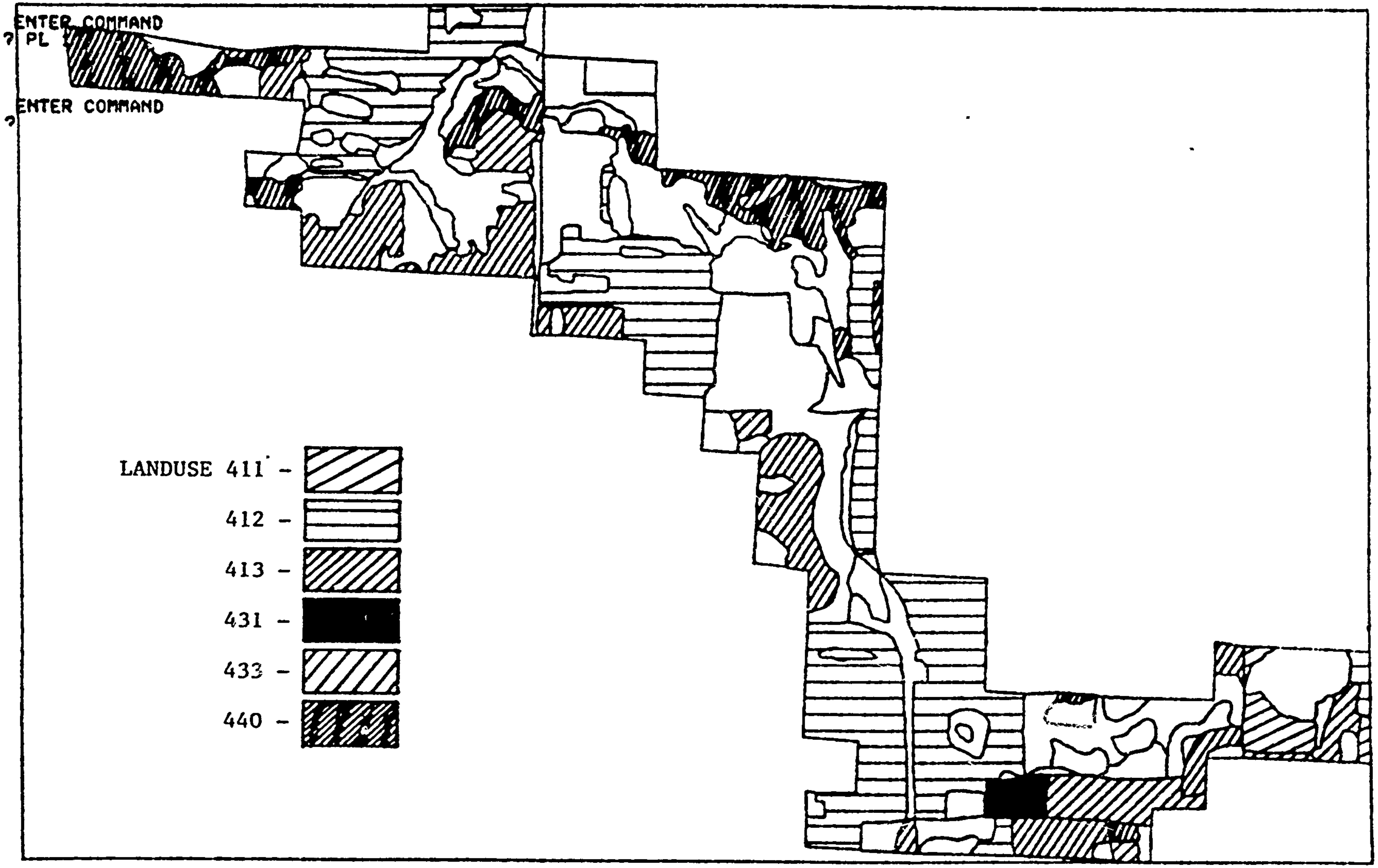


Figure 23 - MOSS Plot of Landuse 412, 411, 433, 413, 440, 431

4.3.3 Data Analysis

Several straightforward analyses were performed on the data.

The first was to determine how many of each structure type fell in each landuse type. The AUTOGIS function used was POINTOVER. POINTOVER allows the user to perform a point in polygon analyses. The result of initiating this function is a new map of points where each point is now tagged not only with its original attribute but also the attribute of the polygon to which it belongs. Table 3 shows the result of using this function. One can quickly see how many structures by type fall within each landuse type. (This analysis function took 5 minutes to perform.)

Using this table and the landuse area tables produced earlier, it was a simple task to produce structure density figures for each land use type. Table 4 shows the figures. It is important to realize that these figures are for demonstration purposes only. To be statistically valid for a large basin, much more sampling would be necessary.

The next analytic function was to convert the LANDUSE polygon data into raster data of various cell sizes. The function in AUTOGIS that performs vector to raster conversion is called POLYCELL. POLYCELL allows the user to create raster data sets at any cell size or X/Y ratio (cell shape), 1.0 being a square cell. However, before the polygon data could be converted to raster format, the coordinate data had to be re-projected from UTM (Universal Transverse Mercator) to Michigan State Plane. This transformation was required so that the raster landuse map would register properly with existing raster data sets for the Clinton study area. The command that performs projection transformations in AUTOGIS is PROJECTION. Twenty projections are supported (Table 5). Once the landuse data were converted to raster format, another AUTOGIS function was used to reformat the raster data into ASCII multivariable grid cell form for compatibility with the HEC/SAM software.

	SUBJECT	NUMBER
412	4	244
412	6	89
411	4	3
411	2	1
411	1	3
433	8	6
413	4	53
411	8	12
230	4	6
210	4	9
433	11	5
440	8	1
413	2	37
431	11	3
412	2	79
412	8	12
220	2	1
412	11	1
300	2	1
413	6	15
230	2	1
413	8	2
300	4	13
440	4	3
440	6	3
413	1	2

FOR MAP LANDSTRUC THERE ARE 26 SUBJECTS

READY?

Table 3 – Subjects for overlay map between landuse and structures. First column is landuse type, second column is structure type, and last column is frequency

TABLE 4

Structure Densities

unit = structure/acre

Structure Type

	1	2	4	6	8	11
210	.000	.000	.061	.000	.000	.000
220	.000	.017	.000	.000	.000	.000
230	.000	.011	.069	.000	.000	.000
300	.000	.009	.118	.000	.000	.000
411	.199	.006	.199	.000	.797	.000
412	.000	.321	.991	.362	.049	.004
413	.022	.404	.578	.164	.022	.122
431	.000	.000	.000	.000	.000	.391
440	.000	.000	.042	.042	.042	.000

TABLE 5 - AUTOGIS PROJECTIONS

0 - GEOGRAPHIC (LATITUDE/LONGTIUDE)
1 - UNIVERSAL TRANSVERSE MERCATOR
2 - STATE PLANE
3 - ALBERS CONICAL EQUAL AREA
4 - LAMBERT CONFORMAL CONIC
5 - MERCATOR
6 - POLAR STEREOGRAPHIC
7 - POLYCONIC
8 - EQUIDISTANCE CONIC
9 - TRANSVERSE MERCATOR
10 - STEREOGRAPHIC
11 - LAMBERT AZIMUTHAL
12 - AZIMUTHAL EQUIDISTANCE
13 - GNOMIC
14 - ORTHOGRAPHIC
15 - VERTICAL NEAR SIDE PERSPECTIVE
16 - SINUSOIDAL
17 - EQUIRECTANGULAR
18 - MILLER CYLINDRICAL
19 - VAN DER GRINTER 1
20 - OBLIQUE MERCATOR

The grid cell data was created at several resolutions: 10 meter, 30 meter, and 1 acre cellsize. The data was registered to the same origin as the existing HEC/SAM database:

N 531940

Origin:

E 2215740

These coordinates are Michigan State Plane data, East zone.

Magnetic tapes of this grid cell data were delivered to the Contract Officer's Technical Representative for transmital to the Detroit District for experimental use.

Several other experimental plots were created and the results are shown in Figures 24 and 25. These plots show a few more examples of MOSS overlay capabilities.

4.3.4 Display

The final manipulation of the Clinton dataset was hardcopy map display. The CALCOMP function in AUTOGIS was used to create all hardcopy displays. Three main map displays were created:

1. A map showing structure locations and structure type (attribute labeling)
2. A black line map showing landuse and landuse type.
3. A shaded landuse map in which each landuse type has a different shade pattern. In addition, each polygon is labeled.

All displays were done in black and white for photo reduction and reproduction purposes.

These hardcopy plots were displayed at a briefing given by Autometric personnel and delivered to the Contract Officer's Technical Representative.

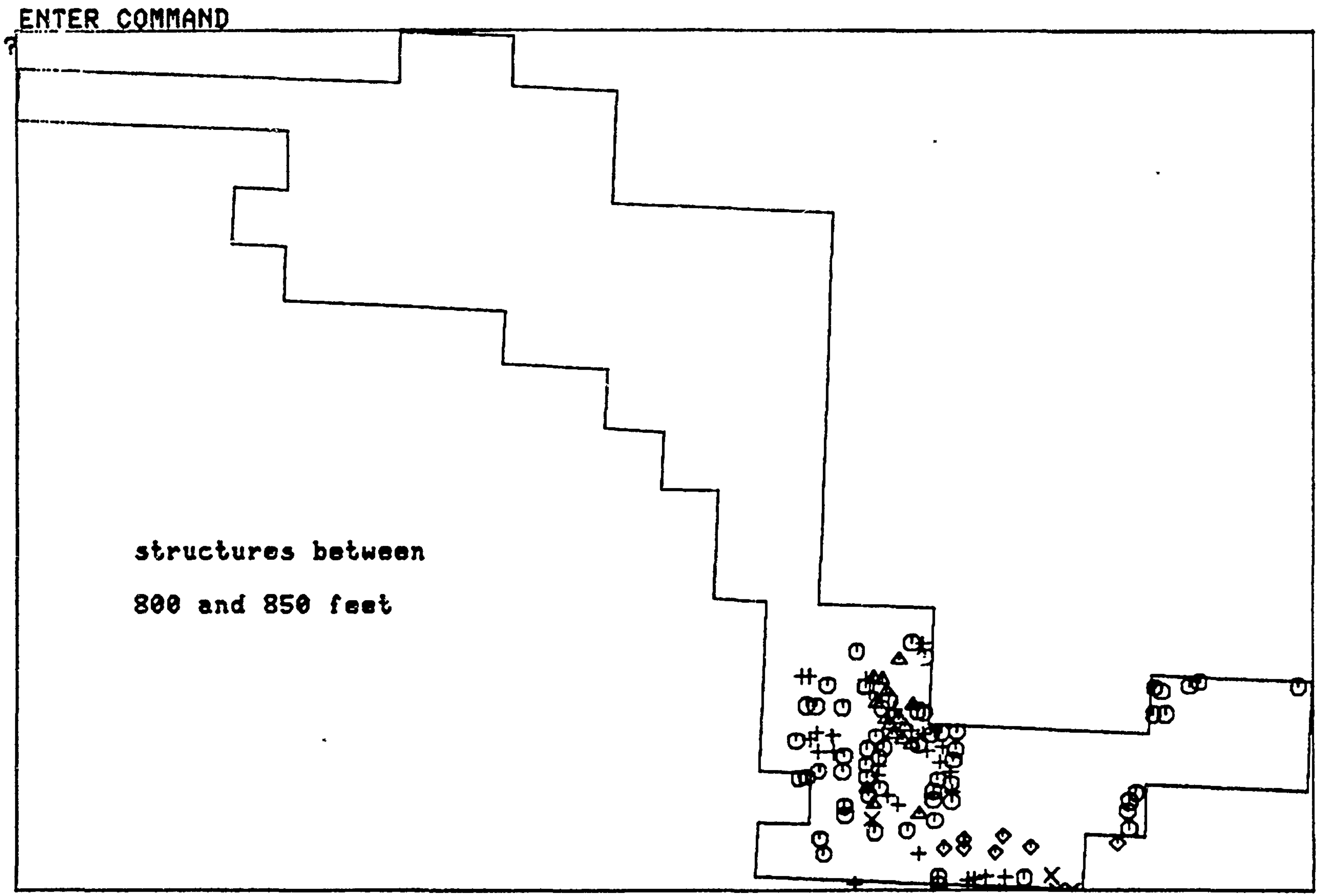


Figure 24 - Experimental MOSS Plot, All Structure Between 800 and 850 Feet

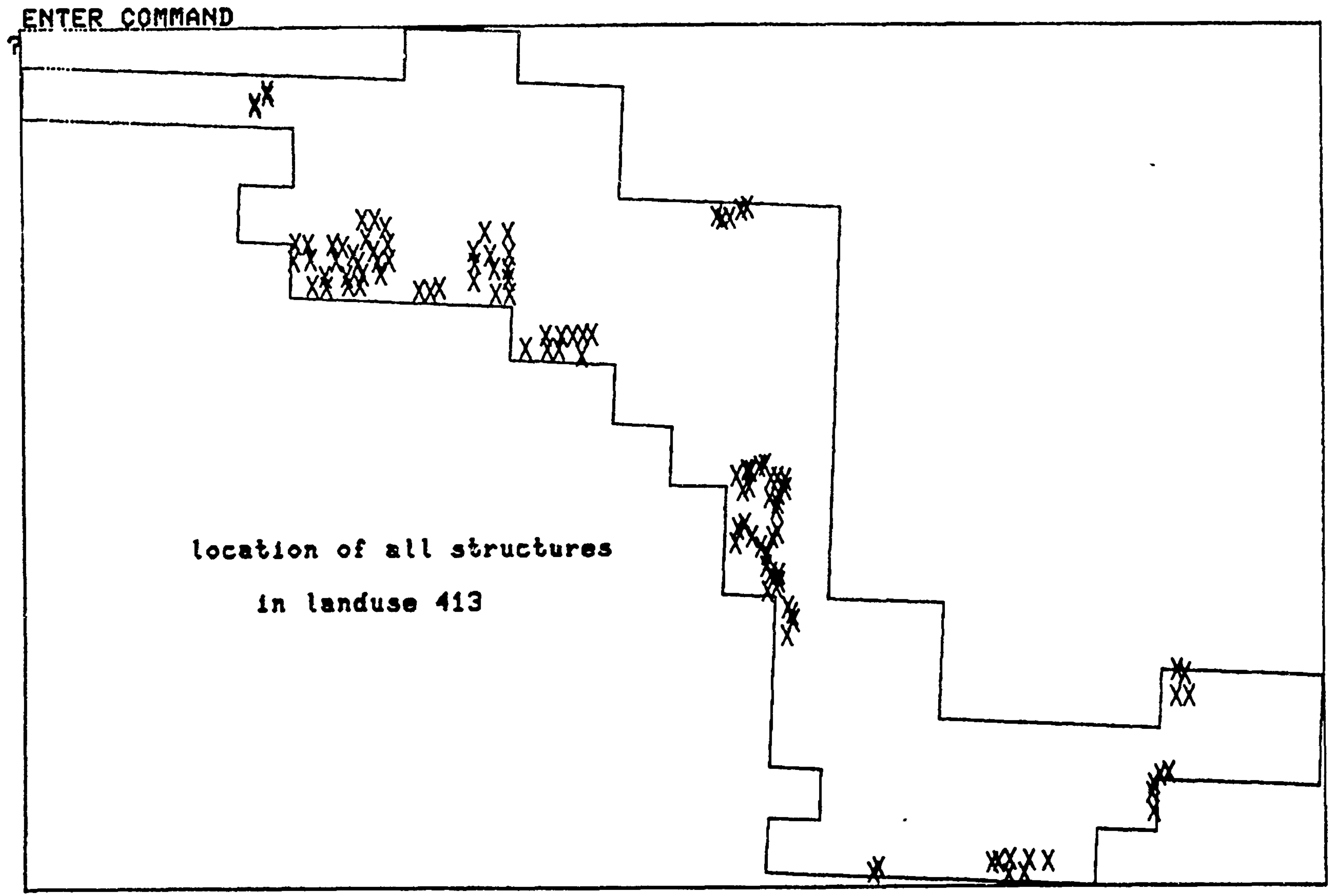


Figure 25 - Experimental MOSS Plot, Location
of All Structures in Landuse 413

4.4 Demonstration Conclusions

The results of this study indicate that the CAPIR system offers useful technology to the Corps of Engineers Civil Works program, both in data collection using the APPS-IV and AMS, and in data analysis and display using MOSS. CAPIR is extremely versatile and effective. This versatility makes it capable of solving many Corps data extraction and data basing problems.

The Clinton River Demonstration showed some of the utility of the CAPIR system. Photogrammetric technology offers an alternative to current labor intensive operating procedures. The use of the same set of photography for land use interpretation and digitization and for a structure survey streamlines a somewhat unwieldly process for extracting data necessary for flood damage predictions.

The CAPIR system can supply this data to the existing HEC/SAM modelling program with previously unrealized accuracy. This improved data resolution, easily available from the APPS-IV, could prompt a reassessment of the modelling procedures. The analytic generality of the APPS-IV and the modularity of the software invite the exploitation of new technology and analysis procedures. The possibility of acquiring actual or simulated imagery from current and future systems (SIR A/B, SPOT, and/or LFC), covering geographic test areas of Corps interest, and using the imagery and collateral data in the CAPIR system, would provide an attractive demonstration program.

It is extremely important to note that the same database developed for flood damage potential assessments can be used in many other applications. This makes the documentation of the potential of the CAPIR system and of the Phase II demonstrations very important to the Corps.

Appendix A: Moss Commands

MOSS COMMANDS

ACTIVE produces a table that numbers and describes the data activated by the SELECTED command. Data can also be activated using the CONTIGUITY and SIZE commands.

ADD allows the data base administrator to add a new map to the master map data base.

AREA produces a table of the area, frequency, and percentage of each subject associated with any polygon map or raster map referenced in the active map table. The area is calculated in acres.

ASPECT allows the user to convert a digital terrain model to an aspect map. The aspect is either degrees from North or one of eight cardinal directions.

ASSIGN allows the user to interactively assign point and line symbologies to point and lineal features. These 'font' assigned features may be plotted with the plot command.

ATTRIBUTE allows a data base administrator to maintain the multiple attribute data files. New attributes may be added, attributes can be updated, and reports can be generated.

AUDIT provides the user with a table containing number of points, subject, item, perimeter in miles, area in acres, and number of islands for each item in a vector map.

BAUD allows the user to reset the internal MOSS baud rate setting. The default is 9600, which can cause considerable delays when using a 300 baud connection.

BLOWUP magnifies a portion of the display window specified by the WINDOW command. The user should display a map on the screen for orientation. The area to be magnified is indicated by pointing to two diagonal corners of a rectangle that bounds the new area of interest. Pointing is done with the CRT crosshairs.

BUFFER computes a user-specified zone around any vector map data referenced in the active map table. The result is a new polygon map which is stored in the polygon workfile.

CALCOMP allows the user to generate a multi-color hardcopy plot on a digital plotter. The user has total control of scale, line type (30 fonts), shade type (angle and density), and labeling. Twenty-two lettering fonts are available. The resulting cartographic product is suitable for meetings, analysis, or publication.

CBUFFER allows the user to perform raster zone generation.

CELLPLOT allows the user to generate a shaded raster map on a digital plotter. Up to nine shade patterns are available.

CLI allows the user to 'swap in' the AOS CLI while still running MOSS.

COMPOSITE LOGICAL allows the user to do boolean manipulations of raster data using one or more maps. The result of combining data with the COMPOSITE LOGICAL command is a new cell map.

COMPOSITE ARITHMETIC allows the user to algebraically manipulate raster data. Maps may be weighted and added/subtracted/multiplied/ or divided. The new map is stored in the data base.

CONTIGUITY helps the user determine "what is next to what?" For example, the user may have a vegetation map and wants to determine how many polygons of ponderosa pine are adjacent or contiguous to polygons of douglas fir. The result of using CONTIGUITY would be a new map of all douglas fir polygons that are contiguous to ponderosa pine.

CONTOUR generates a contour map from a digital terrain model.

COST allows the user to find out how much CPU time and how many disk accesses have been made during a MOSS run. If a costing function is available, it will also print out the cost of the current MOSS run.

DELETE allows the user to delete a map from the MOSS database.

DISTANCE measures the distance in miles and kilometers between two points on the CRT either along a straight line or along a path. The beginning and end points of the DISTANCE measurement are identified using the crosshairs (Cursor) on the CRT.

EDGE activates edge or common boundaries shared by subjects associated with two or more maps referenced in the active map table. The result of the EDGE command is a line map of the common boundaries shared by the input maps.

ERASE clears the CRT display screen and sets the cursor in the upper left-hand corner of the screen.

EXPORT allows the user to generate an ASCII text file from a vector map. This text file is in a suitable format for export to other installations or geoprocessing systems.

FINISH allows the user to terminate the MOSS program. After this command is initiated, the user is returned to the computer operating system. The user can then initiate other programs, or type the word BYE and log off the computer operating system.

FREE is used to 'deactivate' maps referenced by the ACTIVE command.

FREQUENCY produces a table of the frequency and percentage of each subject associated with any polygon map referenced in the active table. Frequency is the number of polygons.

GRID performs point to grid interpolation. This command is used to convert (X,Y,Z) point samples to a digital elevation model.

HELP provides either (1) a listing of the MOSS commands, or (2) a general description of the capabilities of a specific command.

LEGEND allows the user to label points, lines, and polygons displayed on a CRT.

LENGTH produces a table showing the length, frequency, and percent of each subject associated with any line map referenced in the active table. The LENGTH command summarizes in miles.

LIST browses the contents of MOSS map files. The LIST command performs 4 basic tasks:

(1) Lists the names of the maps stored in the master file and the user's cell or polygon workfile.
(2) Lists the subjects for a particular map in the master file.
(3) Lists the Header Information for a particular map.
(4) Browses through the multiple attribute data base on a map.

LOCATE determines the universal Transverse Mercator (UTM) coordinates of any point on the map being displayed on the graphics display terminal.

LPOVER allows the user to perform an intersection between a polygon data set and a point or line data set. The result, another point or line data set, is stored in the user's polygon workfile.

MERGE combines two or more active maps and creates a new map in the polygon workfile.

NUMBER allows the user to either print the items number of each feature in a displayed map or to assign code numbers to groups of features on a displayed map.

OPEN allows the user to access an alternative Master map data base.

OVERLAY synthesizes a new map by determining the polygon intersection between two polygon maps referenced in the active map table. OVERLY uses two active maps as input and creates a new active map as output.

PERIMETER gives the user a list of perimeters in miles for each subject of a given polygon map.

PLOT displays data that have been activated by the SELECT command. Each map set to be plotted is specified using its unique integer code identifier, which may be found by using the ACTIVE command.

POINTOVER performs a polygon on point overlay (Point in Polygon). Typical uses might be to produce a count of all water wells by coal lease area or a count of oil wells by section.

POLYCELL converts point, line, or polygon maps to raster format.

PROFILE allows the user to point with the crosshairs to two locations on a raster map or a digital terrain model and have the surface profile between the two points computed and displayed.

PROJECTION allows the user to coodinate data from one projection or coordinate system to any one of 20 other coordinate or projection systems.

PROXIMITY activates data from a map(s) based on its proximity to some point or other map feature. A typical query for PROXIMITY might be "give me all the ponds within .5 miles of a paved road."

QUERY identifies the map name, subject, and item of any point, line or polygon being displayed on the screen. The user uses the CRT crosshairs to point to the item of interest.

REPORT allows the user to generate tables (reports) up to seven columns wide of data stored in a maps multiple attribute file. These may be up to 200 attributes per map item (point, line, or polygon).

RESET returns the data display window from the new BLOWUP window to the window specified by the WINDOW command.

SAVE saves a map referenced in the active map table as part of the user's workfile.

SELECT activates all or a specific portion of a map that is stored in a MOSS map file. Selection may be an entire map, based on primary subject, based on sub-attributes, or an individual map item.

SHADE plots activated polygon map data on the screen and shades the polygons with differential cross-hatching. If more than one active map ID number is entered following the SHADE command, each map will be plotted with different degrees of cross-hatching.

SIZE activates polygons or lines in an active map based on the size or length of the polygons or lines on the map.

SLOPE enables the user to convert a digital terrain model to a slope map.

SPSS allows the user to generate a data matrix from a set of raster maps. This data matrix is suitable for input into such statistical packages as SAS, SPSS, and BMD. There is also an option to build a multi-variable grid cell file for input into other geoprocessing systems.

STATISTICS CROSS-TABS produces a two way frequency table of the contents of two cell maps referenced in the active map table.

STATISTICS DESCRIBE computes (1) the minimum area or length, (2) the maximum area or length, (3) the total area of length and (4) the range, mean, variance, and standard deviation. These will be computed for each subject associated with an active map.

STATISTICS HISTOGRAM produces a bar graph or histogram of the frequency distribtion of the subjects in any active map (vector or raster).

STATUS prints out the number of items and coordinate pairs for (1) all the maps in the master file, (2) a particular map in the master file, or (3) any map referenced in the active mpa table.

STUDYAREA constructs a new boundary around any map or series of maps referenced in the active map table.

SYMBOL allows the user to select one of 20 symbols and have that symbol plotted for point or polygon data. There are several options to the SYMBOL command.

TESTGRID superimposed a cell grid over any map displayed on the screen. The cell size is user-specified in acres. TESTGRID is useful for helping the user determine the appropriate cell size when converting a polygon map to a call map.

TEXT allows the user to create, edit, and display layers of textual information. The text is tied to the ground and is treated as a special type of MOSS map. Twenty text fonts are available.

THREED allows the user to three dimensionally display any raster map or digital terrain model.

TRANSLATE allows the user to "move" a map from one location on the surface of the earth to another. This is useful for registering data sets.

WINDOW allows the user to set a virtual display window on any vector or raster or set of vector and/or raster maps.

APPENDIX B

Selected Technical Papers Concerning
CAPIR, Its Components, And Its Applications

Brooks, William, and Niedzwiadek, Harry, "The Wetlands Analytical Mapping System Production Environment", Proceedings of the 46th Annual Meeting of the American Society of Photogrammetry, St. Louis, Missouri, March 1980.

Greve, C.W., H.A. Niedzwiadek, R. Bunn, and B. Walsh, "Current and Potential Applications of the APPS-IV Analytical Plotter", Proceedings of the 45th Annual Meeting of the American Society of Photogrammetry, Washington, D.C. March 1979.

Greve, C.W., "The APPS-IV Analytical Plotter", Proceedings of the Analytical Plotter Symposium and Workship, Reston, Virginia, American Society of Photogrammetry, April, 1980.

Greve, C.W., H.A. Niedzwiadek, and G.E. Lukes, "The Implementation of Graphics Superposition on the APPS-IV Analytical Plotter", Proceedings of the 47th Annual Meeting, American Society of Photogrammetry, Washington, D.C., February, 1981.

Greve, C.W., "APPS-IV, Improving the Basic Instrument", Photogrammetric Engineering. 48(6) pp 903-906.

Howland, Jonathan "Surveying and Mapping Applications of the APPS-IV Plotter", Proceedings of the Corps of Engineers Surveying Requirements Meeting, Jacksonville, Florida, February, 1982.

Jackson, Michael, G.R. Hoffman, C.W. Greve, and D.L. Ackerman; "A Parameterization of the ITEK KA-80 A Optical Bar Panoramic Camera System", Proceedings of the Fall Technical Meeting, American Society of Photogrammetry, San Francisco, California, September, 1981.

Lukes, George E., "Geographic Data Bases Supporting Scene Generation", Society of Photo Optical Instrumentation Engineers, Vol. 238, pp. 406-413.

Lukes, George E.," Computer Assisted Photo Interpretation Research at the United States Army Engineer Topographic Laboratories (USAETL)", Society of Photo Optical Instumentation Engineers, Vol. 281, pp. 85-94.

Niedzwiadek, H.A. and C.W. Greve, "The Wetlands Analytical Mapping System", Proceedings of the 44th Annual Meeting, American Society of Photogrammetry, Washington, D.C., February, 1978.

Pascucci, Richard and Alan Smith, "Geographic Information Systems Integration for Quantitatively Determining the Capabilities of Five Remote Sensors for Resources Exploration", Proceedings of the National Energy Conference, Baltimore, Maryland, September, 1982.

Reed, C., "Habitat Characterization: A Production Mode Usage of a Geographic Information System", presented at the 2nd International User's Conference on Computer Mapping Hardware, Software and Data Bases, Harvard University, Cambridge, Massachusetts, June, 1979.

August 1982

APPENDIX C

TEST PLAN FOR CORPS OF ENGINEERS APPS-IV/ CAPIR DEMONSTRATION PROJECTS

Contract: DAAK70-81-C-0261

Prepared for

U.S. Army Engineer Topographic Laboratories
Fort Belvoir, Virginia 22060

Prepared by

Autometric, Inc.
5205 Leesburg Pike
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Falls Church, Virginia 22041

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1. INTRODUCTION

During the past few years many federal agencies have turned to the computer for storing, retrieving, analyzing, manipulating and displaying map information. This trend is especially true of agencies such as the Corps of Engineers (COE) that use remotely sensed imagery to collect information, and develop maps to portray this information for planning and general land management decision making purposes. Many new techniques and technologies have resulted. One of the more notable developments is the Computer-Assisted Photo Interpretation Research (CAPIR) facility at the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia.

The CAPIR system uses an APPS-IV analytical plotter interfaced to a host computer. The APPS-IV is a photogrammetric restitution device designed and developed by Autometric specifically for interactive digital data collection activities involving aerial imagery. The APPS-IV is ideally suited for feature analysis and feature extraction, particularly with the graphics superposition capability, the most recent enhancement to the system. The APPS-IV is interfaced to a minicomputer and a geographic information system called AUTOGIS. The AUTOGIS software, originally developed for the U.S. Fish and Wildlife Service by Autometric and the Federation of Rocky Mountain States and now further developed and supported exclusively by Autometric, provides the tools required to collect or update digital data using either an APPS-IV or XY digitizer, to construct and maintain a multi-layered geographic data base, and to analyze, manipulate or display the contents of the data base. Together the APPS-IV and AUTOGIS form the nucleus of CAPIR.

With the advent of CAPIR type systems, it has become possible for analysts with no formal photogrammetric training to be directly involved in developing and exploiting digital data bases.

2. BACKGROUND

Based on prior Autometric, U.S. Fish and Wildlife Service and in-house USAETL efforts, USAETL is performing work under the Corps' Surveying and Satellite Applications/Remote Sensing research program to evaluate, demonstrate and document the potential of CAPIR technology for Civil Works data extraction, data base development and data base updating applications. As part of this effort, a contract was awarded to Autometric, Inc. to assess potential Civil Works applications and to plan and conduct experiments to demonstrate possible uses of the technology. This work is being conducted as a two phase effort. Under the first phase, Autometric: (1) contacted various Corps districts to identify suitable applications, (2) determined whether or not the respective districts were interested in participating in a demonstration projects, and (3) developed this test plan documenting the work to be performed under the selected demonstrations. During Phase II, Autometric will: (1) perform the demonstrations as outlined in the test plan, (2) prepare an "APPS User Applications Guide" and (3) publish a final report.

3. DEMONSTRATION OVERVIEW

3.1 Objective

The primary objective of these demonstrations is to show how CAPIR type technology can be used by Corps districts to extract, store, retrieve, update, manipulate and display geographic data required in the planning and performance of their terrain and water resources management responsibilities.

3.2 Demonstration Plans

Autometric has developed this test plan to document the work that will be performed during the demonstrations. The Phase II demonstrations will consist of two separate demonstration projects. The first demonstration will be performed in conjunction with the US Army Corps of Engineers, Portland District, and the second in conjunction with the US Army Corps of Engineers, Seattle District, as presented in Sections 4 and 5 of this test plan. The demonstrations will be performed in accordance with this test plan and will include, but will not necessarily be limited to, all the work described in the plan. Should deviations from the plan be required, they will be coordinated with ETL and appropiate Corps district personnel. Final approval for all deviations from the plan will be made solely by the Contract Officer Technical Representative.

3.3 Demonstration Timetable

The timetable for performing these demonstrations is presented in Figure 1.

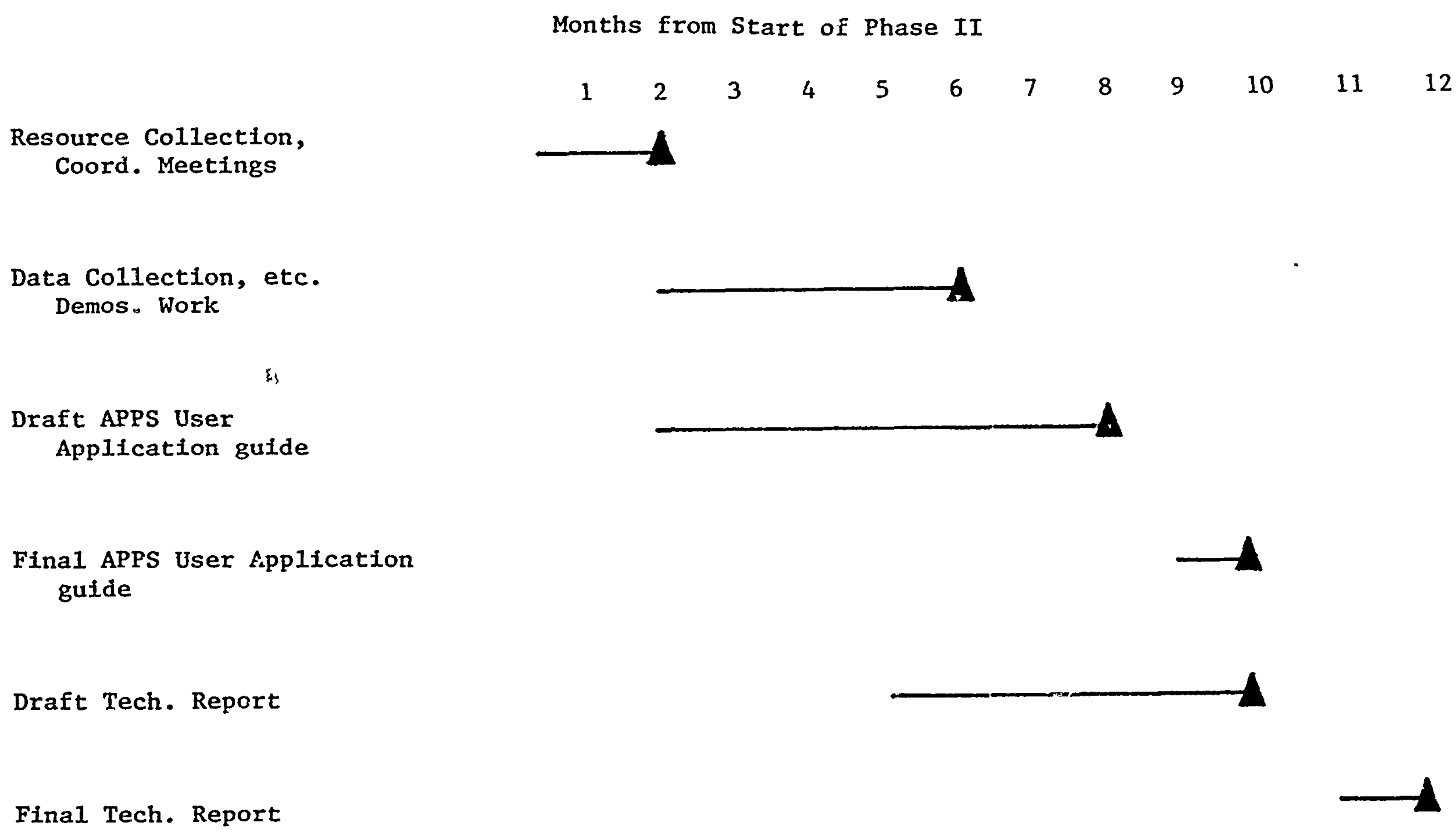


FIGURE 1. TIMETABLE FOR DEMONSTRATIONS

3.4 Coordination Meetings

Upon commencement of the Phase II demonstrations, Autometric and ETL will hold a coordination meeting to define the specific timing and logistics of the tests to be performed.

3.5 Resource Collection

The itemization of necessary resources is covered in detail in Sections 4 and 5. Should it become obvious that data which we plan to use is unavailable or somehow unusable, then the experiment plan will have to be modified to solve the problem.

3.6 Conduct Tests

The format of the actual tests is also covered in detailed in Sections 4 and 5. Briefly, data of various types is digitized, data based, and analyzed.

Complete documentation of all efforts in the demonstrations will be kept. Pertinent items such as cost, time, ease of accomplishment, and procedure will be tracked throughout the process. All demonstration efforts will be recorded on log sheets (see Figure 2) which will be compiled to produce the final documentation and report. Careful note will be made of possible modifications to the procedures. The government will be informed of demonstration status through the vehicle of monthly progress reports, delivered to the Contract Officer Technical Representative. Project status briefings and project reviews will be given upon request to the COTR and District personnel.

DATE:

NAME:

FUNCTION PERFORMED:

START TIME:

FINISH TIME:

PROCEDURE:

COMMENTS:

NOTE: This Log Sheet is only a sample, but the actual log used will be similar

FIGURE 2. DEMONSTRATION LOG

3.7 Briefings

Following the completion of all the demonstrations, Autometric will present briefings to the Districts involved and to ETL personnel. The briefings will cover the work performed in the demonstration and will also serve as a planning/question-answer session for future work and dissemination of the demonstration results.

3.8 Final Report

A final technical report, documenting in detail the work performed during the Phase II demonstrations will be compiled. The final report will include hardcopy output from the CAPIR applications software. Also included in the final report will be suggestions for future use of CAPIR technology. An optimized system configuration specifically tailored for Corps of Engineers production requirements will be developed and presented .

3.9 Facilities and Equipment

CAPIR type equipment located at Greenhorne & O'Mara, Inc. (G&O), Riverdale, Maryland will be used to perform the work in these demonstrations. If the G&O facilities are not available or if funding constraints do not permit use of G&O Facilities, the CAPIR system at ETL will be used on a time available basis to perform the work.

4. COLUMBIA RIVER DEMONSTRATION - PORTLAND DISTRICT

4.1 Purpose

The purpose of this demonstration will be to show how CAPIR technology can be used to create digital data files to monitor rates of accretion/erosion and to map historical changes in wetland areas.

4.2 Background

The Regulatory Functions Branch and Waterways Maintenance Group of the US Army Corps of Engineers Portland District is interested in monitoring historical changes in the wetland areas along the lower Columbia River. The Corps has been conducting regular dredging operations along the lower Columbia River and has been depositing the dredged materials at various sites along the river. These dredging operations combined with natural sedimentation processes have created land areas which did not exist previously. Through the years natural vegetative processes have produced significant wetland habitats. The Corps is interested in studying the types of changes that have occurred and in determining the rate at which these changes occur. The District has aerial photography and other historical data dating back to the 1940's which can be used to create a data base and monitor changes.

4.3 Current Practice

Current techniques used in Portland for monitoring wetlands creation and destruction involved conventional photo interpretation techniques. Skilled photogrammetrists delineate shorelines on historical photography and use a zoom transfer scope to overlay these boundaries onto recent, unrectified photography.

Analysis of the overlays is limited to visual estimates of gains and losses. The visual estimates can then be correlated with vegetation studies performed by Corps biologists to assess the effects of Corps Waterways Maintenance activities.

4.4 Applicability of CAPIR

The CAPIR system will be used to digitize pertinent information from the aerial photography and from other source materials for a specific base year to create a digital data base documenting past conditions. Stereo aerial photography taken during five target years will be used to map land area and vegetation variations from the base year.

Use of CAPIR for this application will offer several advantages. CAPIR allows non-photogrammetrists to perform accurate three dimensional photo interpretation and mensuration. Once the photography has been aerotriangulated, biologists can digitize wetland boundaries, vegetation and/or wildlife habitats directly. The analysis tools of the system allow easy synthesis of scale-independent spatial information, thus freeing Corps personnel from the tedium and inaccuracy of preparing overlays at various scales and attempting to analyze these overlays through manual means only.

4.5 Preparation

4.5.1 Test Site

Based on discussions with personnel from the Survey (photogrammetry) and Regulatory branches of the Portland District Autometric and ETL selected an area of the Columbia River stretching from Rice Island to Tenasillahe Island (Figure 3) for the site of this demonstration. The demonstration will cover Miller Sands, Snag Islands, Jim Crow Sands, Woody Island, and Grassy Island and more if time and funding permit. This area has undergone a great deal of accretion and erosion, due partially to COE waterways maintenance activities.

Northwest Cartography, Inc. has prepared a similar product (bathymetric data only) for the Portland District and the Columbia River Estuary Study Team (CREST). The combination of the two products will be valuable to the Corps of Engineers.

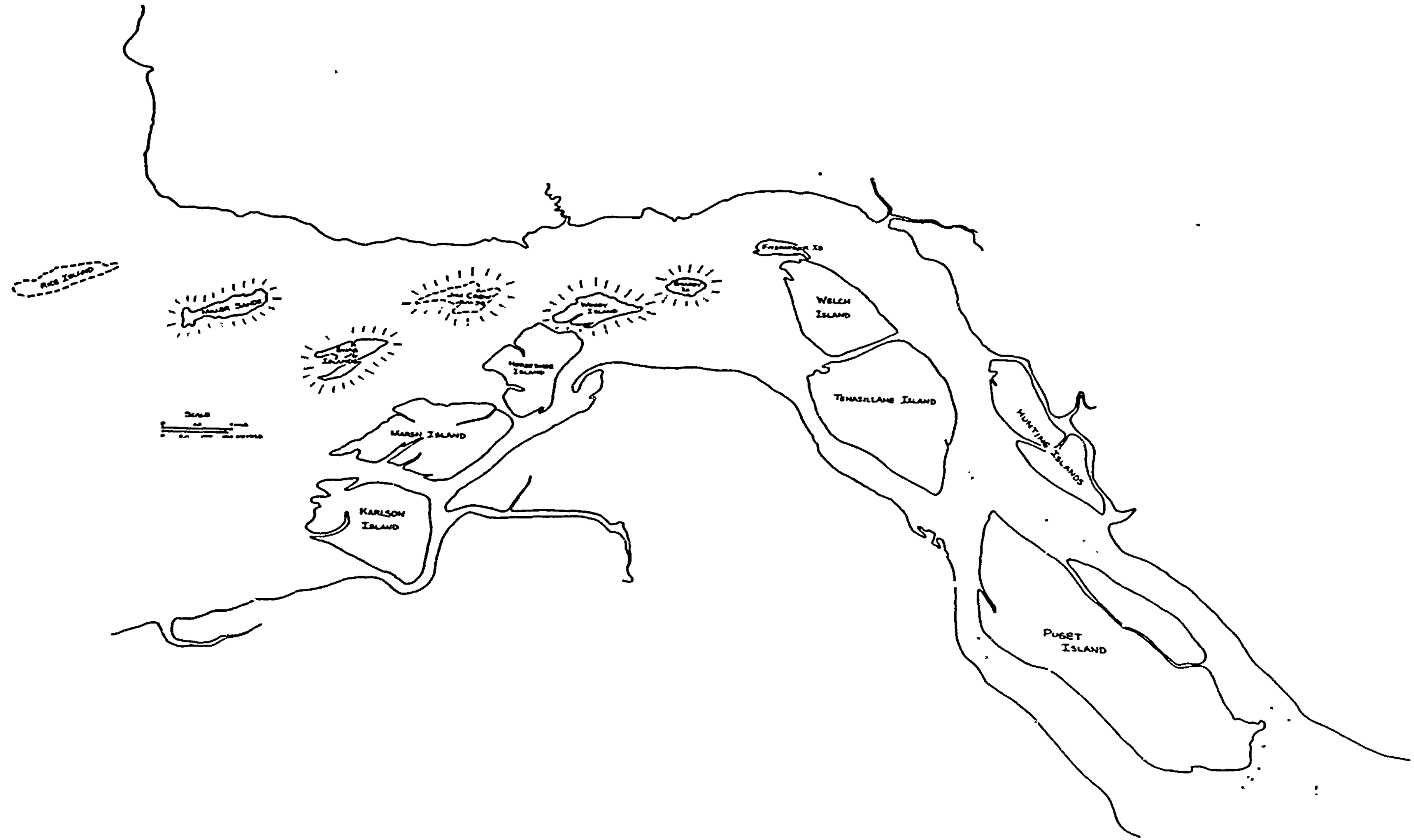


FIGURE 3. DEMONSTRATION AREA, PORTLAND DISTRICT

4.5.2 Resource Collection

Autometric will obtain the following data sources for use in the performance of this demonstration.

4.5.2.1 Aerial Photography

With one exception, all aerial photography used in this demonstration will be obtained from the files of the Portland District. District personnel have indicated that they will be able to provide Autometric with film diapositives of the following imagery:

DATE	TYPE	SCALE	FRAMES
1948	B&W	1:24,000	3558-3560, 3575-3583, 3566-3568
1957	B&W	1:16,800	4901-4904, 4864-4868, 4920-4922, 5031-5037
1966	B&W	1:23,000	674-684, 1034-1036, 1027-1029
1974	B&W	1:24,000	939-952, 960-961, 915-921
1981	CIR	1:48,000	1463-1466, 1481-1485, 1460-1461

All frame numbers refer to the record system of the Portland District. The one exception mentioned previously is six high altitude (scale = 1:130,000) CIR frames from the NASA U-2 program.

DATE	TYPE	SCALE	FRAMES
1974	CIR	1:130,000	2137-2139, 2146-2148

Camera calibration reports for all sets of imagery will be necessary. These are delivered as a matter of contract for Corps photographic missions, and will be obtained from the Portland District.

4.5.2.2 Maps

A complete set of USGS quad sheets covering the area will be necessary, both for digitizing and control purposes. The following 7 1/2′ and 15′ quads will be acquired for use in this demonstration.

Svenson (15′)
Grey's River (15′)
Astoria (7 1/2′)
Cathlamet (15′)
Skamokwa (15′)
Clatskanie (15′)

NOAA nautical charts #18521 (50th edition) and #18523 (38th edition) may also be necessary for digitization and will be acquired.

4.5.2.3 Digital Data

Using their AUTOGIS system the U.S. Fish and Wildlife Service, Western Energy and Land Use Team digitized a large section of the lower Columbia River in 1980 from 7 1/2′ quad sheets, in support of the National Wetlands Inventory. (See Figure 4.) Their files will be input to the AMS data base without conversion or reformatting.

This digitization was an "interim" project, using "rough" copies of the NWI quads and is due to be redone. There may be errors in the data. Nevertheless the data will be valuable in the demonstration and will help

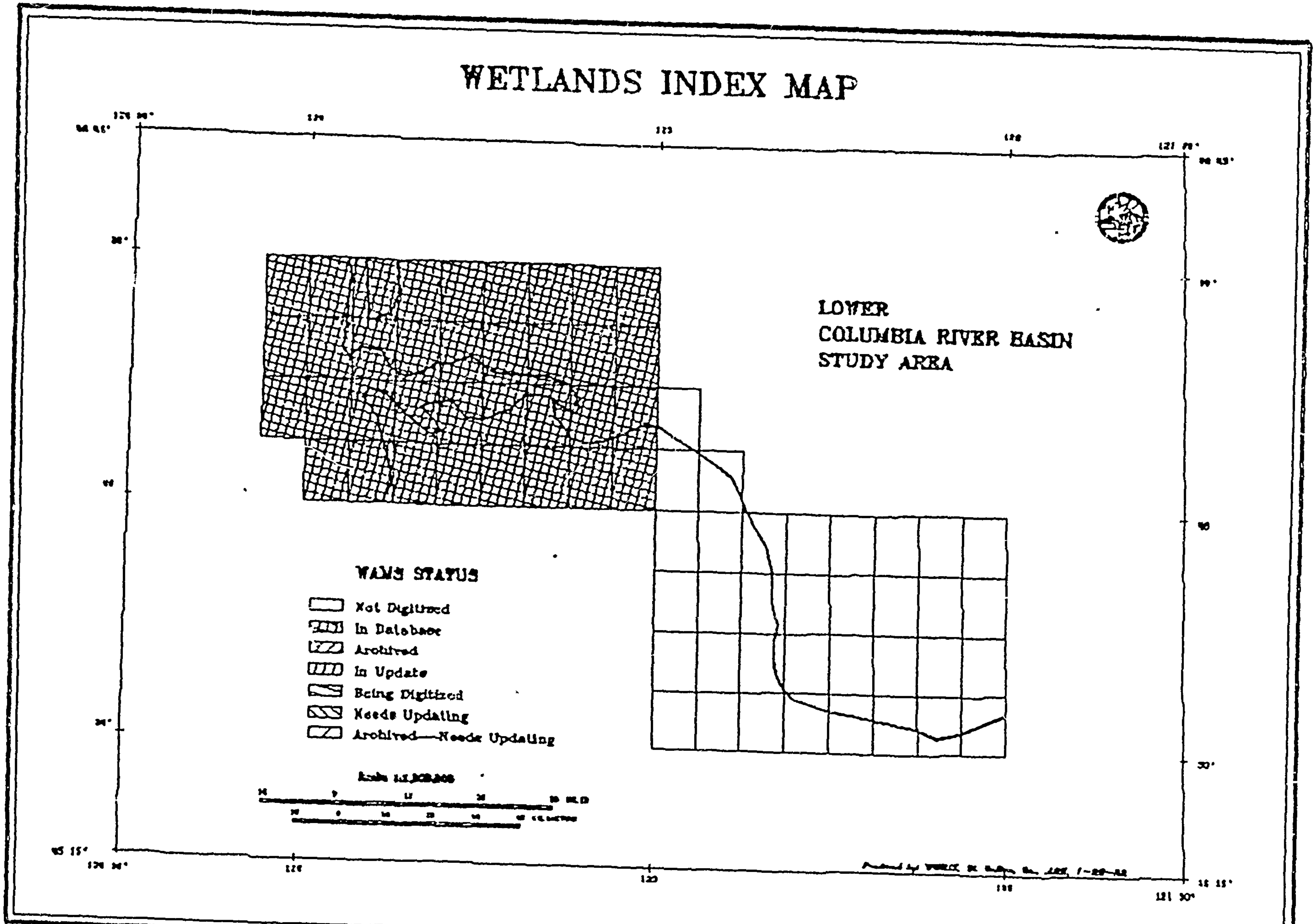


FIGURE 4. NWI DIGITAL DATA COVERAGE

demonstrate how digital data from outside sources can be incorporated into and used in the project data base.

4.5.2.4 Other Requirements

Personnel from the Portland District will provide "training sets" for each of the data categories that will be digitized for this demonstration. (A listing of these categories appears in Section 4.7.2 of this test plan.)

4.6 DEMONSTRATION WORK

4.6.1 Project Definition

When all of the materials have been collected, the project can be set up on the CAPIR system or on similar equipment at G&O. This involves the initial specification of geounits and creation of the necessary files. This procedure is covered in the AMS User's Manual; little deviation from the standard procedure is expected.

4.6.2 Aerotriangulation

The aerotriangulation capability of CAPIR is used to determine the position and attitude of the taking camera at the instant of exposure of a photograph, allowing the reconstruction of the rays which locate the image and true ground position of a point.

A classical block adjustment solution will be employed to simultaneously adjust up to ten photographs. The final computed parameters will be placed into the frame data base to support the digitizing subsystem.

In preparation for triangulation, certain steps are required before executing the program.

Initial estimates for position and attitude of each camera station included in the triangulation and ground control information within the area will be required. Figures 5 and 6 show examples of the forms used to compile this information. Initial estimates for position will be derived from the original flight report (altitude) and by measuring approximate coordinates for the photo centers using USGS quad sheets (latitude, longitude). Estimates for attitude are easily derived since the photographs are near vertical.

Acqiring adequate ground control will be a problem. Much of the imagery covers primarily open water areas of the Columbia River, and photo and map identifiable points are sparse. Available control will be digitized from the USGS quad sheets, and statistics describing its accuracy will be made a part of the final report.

Camera parameters describing the particular characteristics of the taking camera are necessary. These are obtained from the camera calibration reports, entered through the keyboard, and stored in the camera data base.

It will be necessary to perform triangulations for each of the target years listed below.

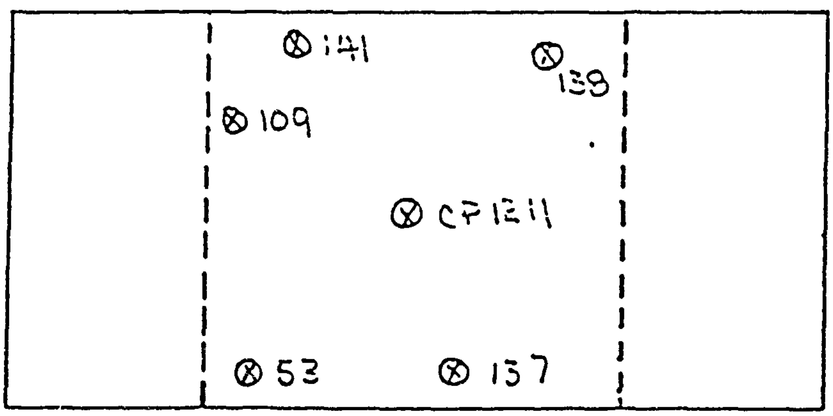
DATE	APPROXIMATE # OF MODELS	COMMENT
1948	7 OR 14	It may be possible to create usable models out of every other photo for this strip
1957	11	
1966	13	
1974	12 or 18	It may be possible to create usable models out of every other photo for this strip

MODEL NUMBER 45

TRIANGULATION INFORMATION

	LEFT FRAME	RIGHT FRAME
MISSION/ROLL ID	F1202	F1203
FRAME ID	CUJ1	CUJ2
CAMERA ID	ZEISS 1	ZEISS 1
LATITUDE	28°-2'-45"	28°-0'-0"
LONGITUDE	82°-33'-45"	82°-33'-45"
ELEVATION	39 400 FT	39 400 FT
KAPPA	270	270
PHI	0	0
OMEGA	0	0

MODEL DIAGRAM



LEFT RIGHT

CHECK POINT ID CP1211
LATITUDE 28-2-00
LONGITUDE 82-33-00
ELEVATION 100 ft
H CLASS 3
Y CLASS 3

DESCRIPTION

center road intersection

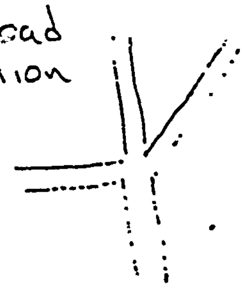


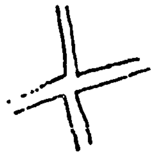
FIGURE 5. SAMPLE TRIANGULATION SHEET

MODEL NUMBER 45

TRIANGULATION INFORMATION

POINT ID 109
LATITUDE 28°-25'-58.64"
LONGITUDE 82°- 8'-38.34"
ELEVATION 78.0 FT
H CLASS 1
V CLASS 1

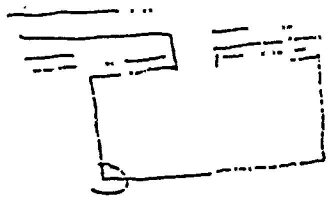
DESCRIPTION



Center of Cross R

POINT ID 137
LATITUDE 28°-22'-49.64"
LONGITUDE 82°- 4 - 1.89"
ELEVATION 90.0 FT
H CLASS 1
V CLASS 1

DESCRIPTION

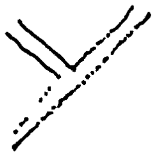


137

SE corner of school parking lot

POINT ID 138
LATITUDE 28°-26'-15.07"
LONGITUDE 82°- 1'- 47.06"
ELEVATION 94.0 FT
H CLASS 1
V CLASS 1

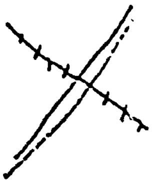
DESCRIPTION



Center sidewalk intersection in city park

POINT ID 141
LATITUDE 28°- 27'- 23.94"
LONGITUDE 82°- 7- 17.36"
ELEVATION 72.0 FT
H CLASS 1
V CLASS 1

DESCRIPTION



Center of inter of RR and Rd

POINT ID 53
LATITUDE 28°- 22'- 4.92
LONGITUDE 82°- 7 - 2.05'
ELEVATION 80.0 FT
H CLASS 1
V CLASS 1

DESCRIPTION

Center of intersection of Rd and Trail E.

FIGURE 6. SAMPLE TRIANGULATION SHEET

4.7 Digitization

Only the areas mentioned earlier and highlighted in Figure 3 will be digitized in each of the target years.

An attempt will be made to maintain National Map Accuracy Standards throughout the digitization process. However, due to the lack of adequate geodetic and identifiable map control in the project area, these standards may not always be met. In any case, statistics describing the accuracy of the digitization will be generated.

4.7.1 Map Digitization

It may be desirable to digitize certain cultural features from USGS quad or NOAA sheets for map sheet registration and orientation purposes. It will also be necessary to digitize photo and map identifiable points from the quads or NOAA sheets for use as control in aerotriangulation process.

4.7.2 Photo Digitization

Most of the data used in this demonstration will be digitized directly from the imagery. The following data categories were selected by Portland District personnel as being significant for their evaluations and will be digitized for each target year:

1. Shallow, permanently inundated areas
2. Shallow, regularly inundated flats
   a. vegetated
   b. non-vegetated
3. Occasionally inundated below ordinary high water line
   a. vegetated
   b. herbaciously vegetated
   c. woody cover
4. Above ordinary high water
   a. vegetated
   b. unvegetated

5. Significantly above ordinary high water (10′ above)
    a. vegetated
    b. unvegetated

As mentioned previously, Portland District personnel will provide training sets prior to this digitization.

4.8 Analysis

4.8.1 MOSS Work

When the data has been digitized using AMS, it will be verified, databased, and transferred to the Map Overlay Statistical System (MOSS), the Analysis and Display component of CAPIR.

MOSS offers 65 different analytical functions and display functions that can be applied to digital data. The use of the data is limited only by the imagination of the user, or by realistic assessment of just what information is desired. The Boolean combination and overlay capabilities of MOSS will be particularly valuable in the Portland demonstration. Input from the Regulatory section of the Portland District will aid Autometric in designing useful data combinations and analyses. Personnel from the Fort Collins, Colorado office of Autometric will participate in the analysis work.

4.8.2 Outputs

Hard copy output (computer generated tables and plots) will be produced for all analyses performed on the system.

Area tables will be an important product.

Graphics from the Portland Demonstration will probably be no larger in scale than 1:24,000. This scale was chosen by District personnel, taking into account the scale of the original digitized photography.

Magnetic tapes containing digital files of the AMS produced vector data will be provided to the ETL and to Portland District.

5. FORT LEWIS DEMONSTRATION - SEATTLE DISTRICT

5.1 Purpose

The purpose of this demonstration will be to show how CAPIR technology can be used to rapidly and accurately create and revise digital data files of information contained in Corps of Engineers Master Plans.

5.2 Background

The Survey/Photogrammetry Section of the US Army Corps of Engineers Seattle District is charged with preparing and updating Master Plans of Army installations in their operating area. These Master Plans contain information regarding general site plans, roads, railroads, water lines, drainage, topography, electrical lines, etc. In areas experiencing rapid development, these maps quickly become outdated and their utility depends on the ability of the planner to remember and hastily incorporate changes that occur after the maps are produced. Synthesis of other types of data with information contained in the Master Plans can be a laborious task since supplementary inputs can vary significantly in scale, format and complexity.

Seattle District is currently in the process of updating the Master Plan for Ft. Lewis, Washington. The currently used Ft. Lewis Master Plan was compiled in 1967 and contains maps and graphics at a scale of 1:4,800 along with 1:2,400 and 1:1,200 scale orthophotos with topographic information over-printed. Certain areas of Ft. Lewis have experienced considerable growth and have undergone significant changes since the 1967 Master Plan was last updated. Consequently, the District is recompiling all the map sheets in the data base from 1:1,200 scale black and white photography acquired in 1979.

5.3 Current Practice

The Seattle District currently prepares the Master Plans using a combination of traditional photogrammetric, ground survey and mapping techniques. The final product is a set of overlays/thematic maps containing the types of information listed above.

5.4 Applicability of CAPIR

Master planning is an ideal use for the CAPIR system. Digital data bases can be rapidly developed and updated. Once in digital form, various data types can be merged and analyzed independent of the scale of the original source material. A planner can use the analytical tools of the system to extract precisely the information he needs from the digital data base and can produce hardcopy outputs of synthesized products at virtually any scale.

The CAPIR system will be used to create a digital data base from existing maps and source material which can then be revised and updated using recent aerial photography. For this demonstration the existing manuscripts from the 1967 Fort Lewis Master Plan will be digitized and newly acquired photography will then be used to update the digital data in those areas where changes have occurred.

5.5 Preparation

5.5.1 Test Site

Based on discussions with Seattle District personnel, an area of Fort Lewis that has undergone rapid development in recent years, was selected as the test site for this demonstration. The test site is entirely contained within map sheet number 7 of the 1967 Fort Lewis Master Plan.

The area is bounded by the following coordinates (Washington Lambert Coordinate System, South Zone).

North	649,000
North	640,000
East	1,487,000
East	1,482,000

This is an area of 45,000,000 square feet, or 1037 acres.

The test site contains examples of many data variables useful in Corps master planning.

5.5.2 Resource Collection

Autometric intends to obtain the following data sources for the demonstration.

5.5.2.1 Aerial Photography

The Seattle District has offered to fly new photography of the test area pending approval of this plan.

The photography will be at a scale of 1:4800 and will be supplied in the form of film positives.

The District has also offered to pug and aerotriangulate the strip and furnish Autometric with a control abstract and camera calibration report.

5.5.2.2 Maps

The Seattle District has already provided ETL with appropriate sections of the 1967 Master Plan of Fort Lewis. These maps are at a scale of 1:4800.

Seattle District will also furnish a 1:1200 (1979) orthophoto with legible 5′ contour lines.

Automatric will also require the USGS quad sheet covering the Fort Lewis area.

5.6 Demonstration Work

5.6.1 Project Definition

After all of the materials have been collected, the project will be set up either on the CAPIR system or on similar equipment at G&O. This involves the initial specification of geounits (map parcels in digital form) and creation of the necessary files. This procedure is covered in the AMS User's Manual; little deviation from the standard procedure is expected.

5.6.2 Aerotriangulation

The aerotriangulation capability of CAPIR is used to determine the position and attitude of the taking camera at the instant of exposure of a photograph, allowing the reconstruction of the ray which locates the image and true ground position of a point.

A classical block adjustment solution will be employed to simultaneously adjust up to ten photographs. The final computed parameters will be placed into the frame data base to support the digitizing subsystem.

As previously mentioned, the Seattle District will aerotriangulate the strip of photography they are supplying.

Autometric intends to perform another aerotriangulation of the same strip on the CAPIR system. Initial parameter estimates for the triangulation and ground control information will be derived from the Seattle triangulation. Camera parameters will be entered through the keyboard.

Careful documentation of the process and a comparison of the results of the two solutions will provide useful data for the demonstration.

It will probably be necessary to triangulate no more than 7 photos for this demonstration.

5.7 Digitization

The demonstration will involve digitizing from two source types, maps and aerial photography, to create a digital data base of the Fort Lewis Master Plan. An attempt will be made to maintain Class A National Map Accuracy Standards (at data base scale/resolution) throughout the digitization process.

5.7.1 Map Sources

The initial digitization will be performed on the 1967 Master Plan, and will involve some or all of the following categories:

1. Buildings
   a. permanent
   b. semi-permanent
   c. temporary
2. Pavement
   a. primary roads
   b. secondary roads
   c. tertiary roads
   d. parking areas
3. Water Facilities
   a. mains
   b. valves
   c. hydrants
4. Sewer Facilities
   a. mains
   b. manholes

Contours will be digitized directly from the 1:1200 orthophotos.

5.7.2 Photo Sources

The data base created by digitizing the map products will be edited using the newly flown photography. Using the APPS-IV and AMS the digital files of buildings and pavement and other photo identifiable data categories will be updated.

5.8 Analysis

5.8.1 MOSS Work

When the data has been digitized using AMS, it will be verified, databased, and transferred to the Map Overlay Statistical System (MOSS), the Analytical Display component of CAPIR.

MOSS offers 65 different analytical functions and display functions that can be applied to the digital data.

In this demonstration, Autometric will solicit input from the Seattle District concerning desired system outputs and analyses. The system architect of MOSS will be part of the analysis team, ensuring optimum use of the systems capabilities in desired analysis/display.

5.8.2 Outputs

Hard copy output (Computer Generated tables and plots) will be produced for all analyses performed on the system.

The probable output of the Seattle demonstration will be a series of 1:4800 plots showing various useful combinations of building, road, water, and sewer data as developed using MOSS. Three dimensional views of the terrain as compiled from the contours may also prove to be useful, and will be produced. Statistical area tables and other tabular information will be printed.

Magnetic tapes containing digital files of the AMS produced vector data will be provided to the ETL and to Seattle District.